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Abstract

The Autonomous Acoustic Buoy (AAB) has been designed and manufactured by Laboratori d'Aplicacions Bioacústiques (LAB) with the assistance of Universitat Politècnica de Catalunya (UPC) over the past two years. This is due to the need to measure and control the correlation between human activity and presence of marine mammals in the marine environment. The buoy is used for recording sound patterns in the underwater environment, specifically referring to the physiological and neurophysiologic processes by which sounds are produced, received and processed [42]. Furthermore the AAB has an important role in monitoring and identifying the communication between marine mammals. This paper presents the further advancements and improvements of the design and functionality of the AAB as well as a concise introduction into the buoy capabilities and a brief overview of the history, purpose and organisation of the LAB. With regards to the improvements made this article gives details of elaborate research undertaken into dolphin whistles analysis and a well structured marketing plan. The mechanical and electrical features concerning the safe operating conditions of the buoy offshore are also presented within this report.

Key words:

Autonomous, Acoustic data, Buoy, CAD, dolphin whistles, marketing, microcontroller, product introduction, sensors, simulations, *watchdog*.

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1. Introduction

Over four and a half months, *Universitat Politècnica de Catalunya* (*UPC*) in collaboration with *Laboratori d'Aplicacions Bioacústiques* (*LAB*) has organised the third edition of *European Project Semester 2010* (EPS). The purpose of this course is to provide a project by the collaborative work of international students. This is carried out in a multicultural environment at the same time bringing students into contact with real tasks performed in professional situations [43].

The company, for which the *Autonomous Acoustic Buoy* (*AAB*) project is carried out, is the *LAB (see Fig. 1)*. Established in 1997, the *LAB* is a multi-disciplinary research group of scientists who are searching for a solution to the increasing acoustic degradation of the marine habitat in the Mediterranean Sea and the North Atlantic. The *Laboratory of Applied Bioacoustics* was created at the proposal of Michel André with a grant from the *Spanish Ministry of Science and Technology* and the institutional support from the *City of Vilanova i la Geltrú* and the *Ports Directorate of the Catalan Government.*

Fig. 1 LAB logo

With the cooperation of the *UPC* and the *Centre Tecnològic de Vilanova I La Geltrú* (CTVG), the *LAB* has created the AAB to record sounds in the marine environment without introducing noise pollution from active sources such as sonar [39]. These recordings can then be studied and analysed. As an additional activity, the *LAB* is also involved in the organisation and teaching of different courses, such as: *Master on Marine Technologies and Acoustic Sensing* or *Cetacean Bio-sonar and Communication*.

The *Autonomous Acoustic Buoy* (*AAB*) is a system used for acoustic monitoring different types of sounds in the underwater environment. It has been designed in the shape of a miniature ship in order that it can easily be transported and used in both offshore and onshore environments. The shape of the buoy is crucial as it is not self propelling and is very heavy, this aerodynamic shape allows it to efficiently be towed to its location by another vessel. In addition the *AAB* has its own computing platform used to record the desired sounds by selecting them with a programmable high pass filter. This filter has been designed to select whistles after first comparing process of sounds with references and was designed by 2009 EPS students. The AAB gives users the option to both record and listen in real time [3], to natural (e.g. cetaceans) and artificial sounds(e.g. from shipping) at different locations.
The main purpose of using the *AAB* is to study the effects produced by ocean noise on cetaceans. Manmade noise is the result of different anthropogenic activities, such as the following:

- Marine navigation;
- Offshore natural resources exploration and extraction;

- Civil engineering activities;
- Military activities;
- Windmill parks; [5,6,7]

As well as being an impediment in communication processes between cetaceans and marine environment such as displacement process or food sources, noise can also produce serious injury to marine mammals. Traumas associated with noise pollution can result in an either lethal or sublethal impact. In the case of sublethal impact on the cetaceans hearing aid refers to:

- Stress;
- Disorientation;
- Internal bleeding; [8,9]

Recovery time can vary between a few hours and a few weeks depending on the individual and the severity of damage. However, repetitive exposures to sound sources without allowing adequate recovery periods can be fatal [9]. Also in the knowledge and understanding of the acoustic sounds made by marine mammals the *LAB* can help to avoid whale and ship collisions thus preventing serious injury or death of the mammals concerned.

Our project has been broken down into four subsections dictated by the knowledge and enthusiasms of the students within the group.

Electronics - Ion Huştiuc & Fèlix Hill

The electronic section of the AAB project will design and implement a *watchdog* that will monitor both the physical and software condition of the Hercules board. This is the core of the Autonomous Acoustic Buoy operating both the power supply module and the *watchdog* itself.

Marketing - Samantha van den Berg

The marketing section is responsible for designing a plan to enter the AAB on the global market.

Bioacoustic Analysis - Maciej Ditrych

The Bioacoustic analysis section will examine and classify different sounds produced by dolphins, these sounds are formally known as whistles.

CAD Simulation – Andrea Johnson

The Buoy will be simulated in a variety of situations in order to test its behaviour in the marine environment.

In conjunction with research and analysis done by both the *Laboratory of Bioacoustics Application* sand EPS students the *AAB* can provide the key to a sustainable solution for the protection of cetaceans against human activities in the marine environment.

2. Dolphin whistle Analysis

2.1 Introduction

Traditionally dolphin's recognition techniques are based on the photographic identification of various obstacles or other groups of dolphins. As well as these photographic methods they also use sound identification enabling them to recognize objects for example group size or bottom structure. Dolphins are capable of making a wide range of sounds by using their nasal air sacs which are located close to the blowhole. In general dolphins are able to produce three types of sounds: clicks, burst-pulsed sounds and finally whistles. Dolphins communicate with each other using whistles and burst-pulsed sounds however the exact nature and extent of this communication ability is not yet known. It is also believed that some dolphin species can identify themselves using a signature whistle. Clicks are used for echolocation and primarily occur in short series called click trains. The rate of clicks increases as the dolphin is approaching an object of interest. Dolphin echolocation clicks are one of the loudest sounds that are produced by marine mammals.

In recent years noise pollution has become a serious issue affecting marine mammals. Anthropogenic sounds (man-made noise) can inhibit a cetacean's ability to navigate, find food, rest and locate others (for protection or mating) among a number of other essential activities. Man-made noise arises from a variety of sources such as oil drilling, sonar testing, explosives and seismic surveys; however the majority of man-made sound in the ocean is produced by shipping.

A research group named Laboratori d'Aplicacions Bioacústiques (LAB) with assistance of Universitat Politècnica de Catalunya (UPC) examines the sounds in seas and oceans. They also investigate the effects of manmade noise on cetaceans. During the European Project Semester (EPS) previously recorded whistle patterns will be analysed and classified. It is possible to distinguish one species from another on the basis of its specific whistle characteristics and variables. In order to do this precise research on the already examined whistles will be done using the aid of scientific papers. Once this is completed appropriate software can be utilised to set the parameters and begin the process of classifying whistles.

The Autonomous Acoustic Buoy records information on the sound patterns produced by cetaceans. In addition to this the LAB has a database of a wide collection of recordings of the noise produced by marine animals. One such sound that features in this collection is that of whistles; these are a specific type of sound which is produced for the most part by dolphins. In order to further understand the communication processes and behaviours of marine creatures such as dolphins these whistles need to first be analysed and secondly classified to the particular species which produced them.

2.1.1 The way in which dolphins produce sounds

There are more than forty species of dolphins on our planet. They can be found worldwide in the shallower seas for the most part in close proximity to continental shelves. It is a common belief that Dolphins are one of the most intelligent animals in the world and in addition they have got very friendly appearance. This in turn makes them very popular among humans.

Although sounds produced by Dolphins primarily originate underwater they are also able to produce sounds in the air. Dolphins produce sounds in air by releasing air from their blowholes. In this way sound patterns are controlled by dolphins grate muscles, by changing the shape of these they can alter the sound patterns produced. Sounds, which are produced underwater, are generated inside the dolphin's head underneath the blowhole without air escaping from the blowhole itself.

Two hypotheses can be found about the production of these under water sounds:

- The first such hypothesis and the most popular is called the nasal sac theory. This hypothesis states that sounds are produced in three pairs of air sacks located under the blowhole. When dolphins breathe in, their blowholes are closed and air returns from the lungs into the channel leading to the blowhole and into one or more of the air sacs. The air is inflated into the sacs, then it is forced out of the air sac and over the nasal plug (which is located just at the opening of each air sac) resulting in sound production.

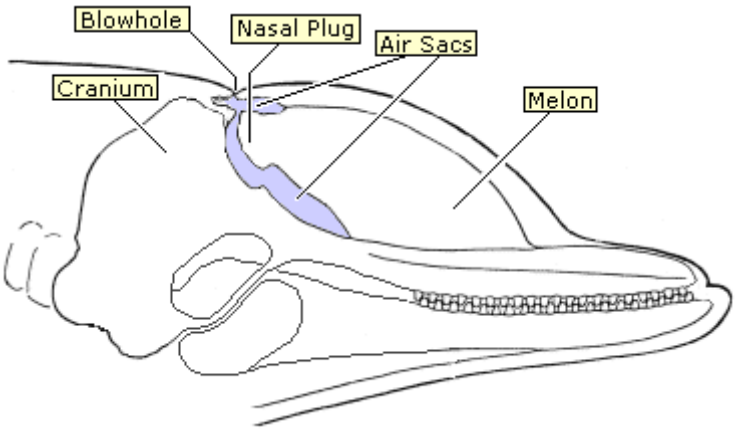


Fig. 2 Air sack location www.dosits.org/images/dosits/dolphin2222.gif

- The second hypothesis states that, when the sound is produced by some small knobs or fatty tissues beneath the blowhole, the air sacs focus that sounds. This tissue functions similarly to our lips which are able to flap together when air is pushed past them. In this way a pulse is created and is transmitted out into the water.

Scientists are not able to confirm either of these hypotheses because no one has ever seen a dolphin's head whilst it is in the process of producing sounds. Medical

equipment is in existence that is capable of carrying out such an examination however it is too difficult to be used with dolphins. Moreover, it can be simply detrimental to their health. Perhaps one day in the near future new technology will become available that will allow such scientific research to be carried out.

As for the sound reception, scientists currently believe that specialized fatty tissues in the jaw region serve as the primary route able to pick up sound to the middle and inner ears. This is known as the pan bone theory.

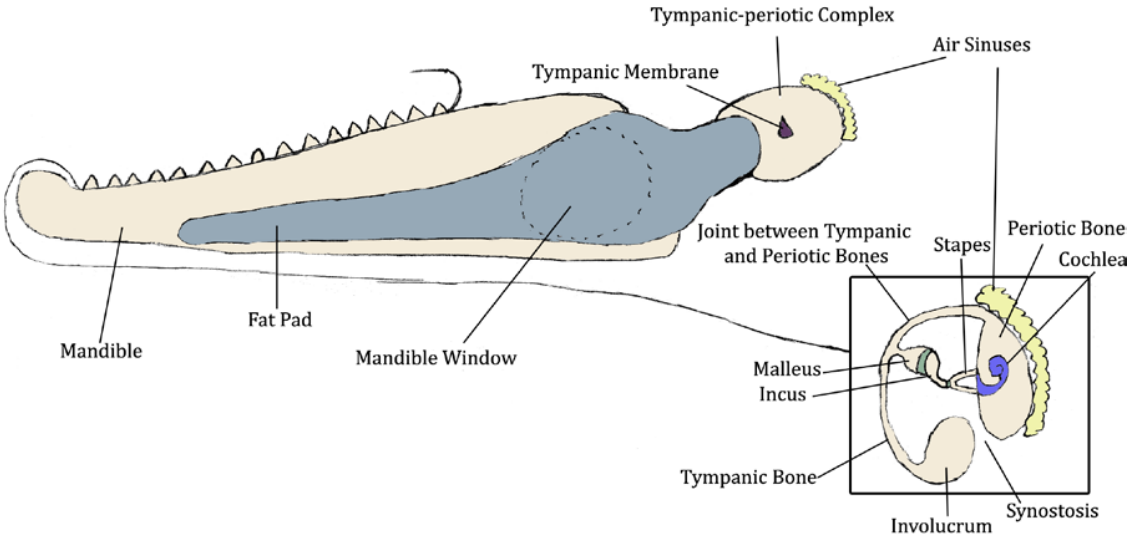


Fig. 3 Drawing of general delphinid sound reception cross-section from the left-hand side. Inset: 90° counter-clock wise rotation cross-section of tympano-periotic bone bulla[11]

2.1.2 Types of sounds

Dolphins produce many types of sounds, both when they are underwater and above the water surface. The three that are most well-known are whistles, clicks, and burst pulse sounds. The graphical relation between the frequency and the time of those sounds are commonly presented by using spectrograms. *Figure 4* below shows the frequency ranges and durations of different underwater sounds.

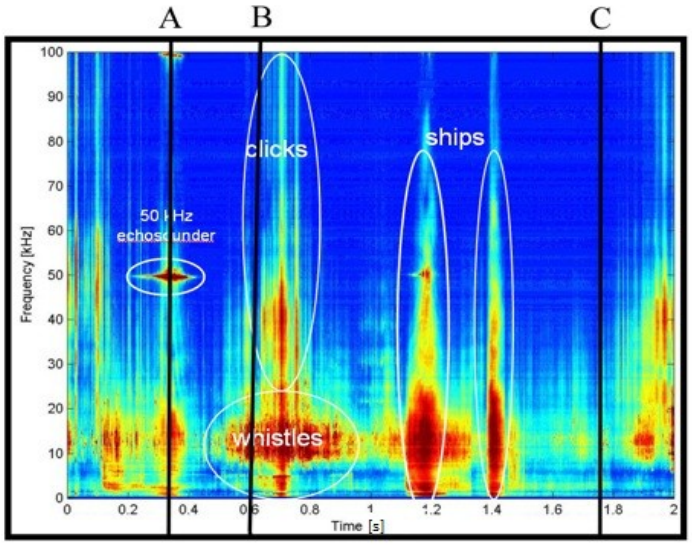


Fig. 4 Example of spectrograms of whistles, clicks or other sounds, which were recorded underwater

2.1.3 Whistles

Dolphins produce many different types of whistles. One whistle which dolphins use most There are many types of whistles produced by dolphins, but generally their frequency is in range from 4 kHz to 20 kHz and their duration is not longer than 1,4 s. Whistles are subdivided into 21 categories, based on the contour structure and shape obtained from spectrograms. It is believed that dolphins use whistles mainly for communication with each other *[12],* more rarely it is thought that whistles are used for the expression of emotions or feelings in the same way as burst pulse sounds. Dolphins produce individual signature whistles, these are unique and therefore enable them to identify individuals. Dolphins have also an excellent ability to mimic and copy the signature whistles of other individuals. Calves are still developing their signature whistles up to six months after being born.

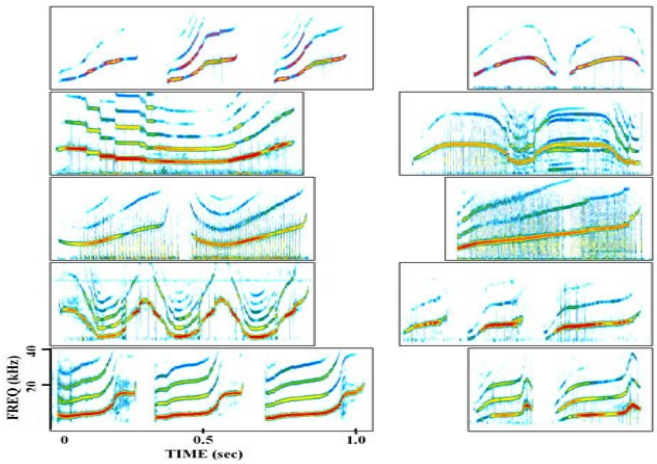


Fig. 5 Examples of different types whistle spectrograms(www.sarasotadolphin.org)

Whistles consist of harmonics and steps, which make each whistle different. For analysis of whistles, very important are the following parameters: number o steps,

number of harmonics, number of breaks, initial frequency and the final frequency, maximum and the minimum frequency as well as mean frequency. The *Fig. 6* shows an example of a whistle with all of the mentioned features presented.

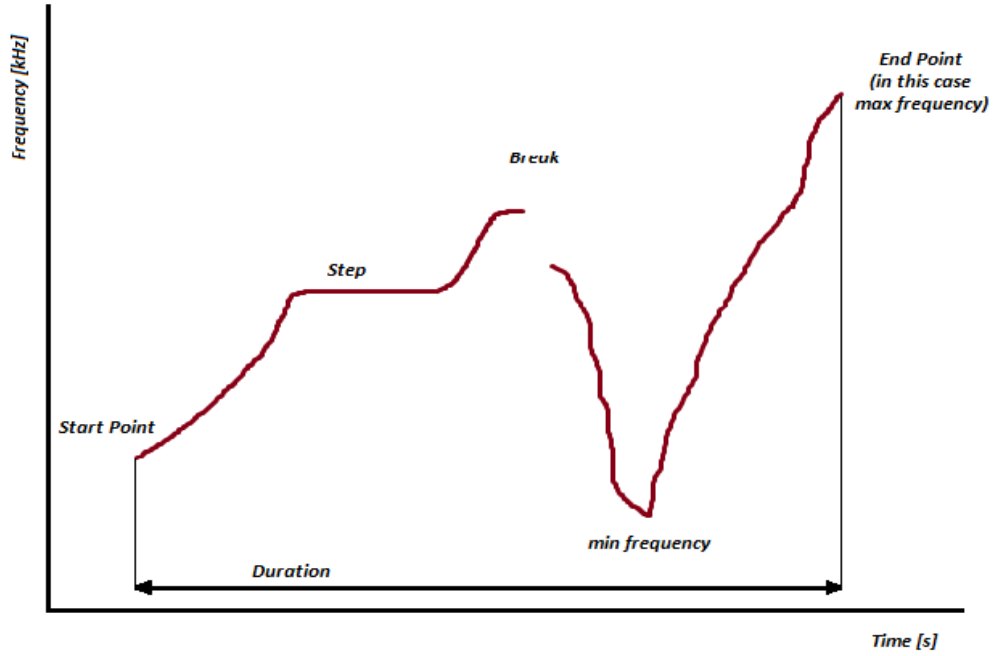


Fig. 6 Example of a whistle with all of its features included (based on Emily T. Griffith, 2009)

2.1.4 Clicks

Clicks are used exclusively for echolocation; this is dolphin's significant ability to identify objects by the means of using sound. Dolphins are also able to detect obstacles by creating sound patterns and then receiving them back. In addition dolphins are also able to receive information about an objects structure through the use of echolocation techniques.

Clicks are produced in click-trains which are rapid sequences of sounds. The range of frequency of clicks is very high in comparison to whistles, it is from 0,2 kHz even up to 150 kHz *[13]*. Dolphins use lower frequency clicks only for detection of objects that are further away as low frequency sounds are able to travel further. Lower frequency clicks don't contain detailed information; this can help to explain why dolphins increase the frequency of click's as they move closer to an object.

2.1.5 Burst Pulse Sounds

Barks, mews, chirps and pops, these are the group of sounds categorised as Burst pulsed sounds. The reason why dolphins use them is not known for sure, but it is believed that they produce such sounds under emotional duress i.e. when they are angry, frustrated, frightened or upset. These sounds are mainly directed towards other dolphins, humans or inanimate objects.

2.2 Dolphin whistle research

In order to perform the analysis and classification of the recordings provided by LAB, a complete research on dolphin whistles was first carried out. This was completed using scientific reports and publications available online as well as sound parameters (in particular time and frequency characteristics) of different whistles that were extracted and gathered along with the geographic location maps. Because dolphins (even ones of the same species) in different locations produce sounds of various parameters, the research part has been divided into two main categories. These categories are that of whistles produced by Pacific region dolphin and whistles produced by Atlantic region dolphins. The Pacific region section contains whistle information about species from the northern part of Australia to the Eastern Coast of North America in the Pacific Ocean. In contrast the Atlantic region section contains information about dolphins living in the Atlantic together with the Mediterranean Sea.

In addition to this research into potential software for the analysis of dolphin whistles was carried out however no appropriate program was found. As a result whistles were further analysed in Matlab software and on this software and its functions was performed.

2.2.1 Dolphins taken into consideration

There are not many sources containing information about dolphin whistles. However the Bottlenose dolphin and Common dolphin, especially Short-beaked common dolphin, were the species for which it was the easiest to find information. Due to the difficulties faced in obtaining information only 13 species from a total of 37 were taken into consideration for further research.

Table 1 Dolphins included in the research

Species taken into reasearch		
1	Cephalorhyncus commersonii	Commerson's Dolphin
2	Cephalorhyncus eutropia	Chilean Dolphin
3	Cephalorhyncus heavisidii	Heaviside's Dolphin
4	Cephalorhyncus hectori	Hector's Dolphin
5	Delphinus capensis	Long-beaked Common Dolphin
6	Delphinus delphis	Short-beaked Common Dolphin
7	Delphinus tropicalis	Arabian Common Dolphin
8	Feresa attenuata	Pygmy Killer Whale
9	Globicephala macrorhyncus	Short-finned Pilot Whale
10	Globicephala melas	Long-finned Pilot Whale
11	Grampus griseus	Risso's Dolphin
12	Lagenodelphis hosei	Fraser's Dolphin
13	Lagenorhynchus acutus	Atlantic White-sided Dolphin
14	Lagenorhynchus albirostris	White-beaked Dolphin
15	Lagenorhynchus Australis	Peale's Dolphin

16	Lagenorhynchus cruciger	Hourglass Dolphin
17	Lagenorhynchus obliquidens	Pacific White-sided Dolphin
18	Lagenorhynchus obscurus	Dusky Dolphin
19	Lissodelphis borealis	Northern Right Whale Dolphin
20	Lissodelphis peronii	Southern Right Whale Dolphin
21	Orcaella brevirostris	Irrawaddy Dolphin
22	Orcaella heinsohni	Australian Snubfin Dolphin
23	Orcinus orca	Orca(Killer Whale)
24	Peponocephala Elektra	Melon-headed Whale
25	Pseudorca crassidens	False Killer Whale
26	Sotalia fluviatilis	Tucuxi
27	Sousa chinensis	Pacific Humpback Dolphin
28	Sousa plumbea	Indian Humpback Dolphin
29	Sousa teuszii	Atlantic Humpback Dolphin
30	Stenella attenuata	Pantropical Spotted Dolphin
31	Stenella clymene	Clymene Dolphin
32	Stenella coeruleoalba	Striped Dolphin
33	Stenella frontalis	Atlantic Spotted Dolphin
34	Stenella longirostris	Spinner Dolphin
35	Steno bredanensis	Rough-toothed Dolphin
36	Tursiops aduncus	Indian Ocean Bottlenose Dolphin
37	Tursiops truncatus	Common Bottlenose Dolphin

2.2.2 Whistle parameters

The Next step of the research phase was the extraction of data with regards to the whistle characteristics for individual species. All of the gathered parameters are presented in the tables below. The following characteristics were taken into account: duration, mean frequency, minimum and maximum frequency and finally the start and end point of the whistle.

Table 2 Whistle parameter table for Atlantic region section

Specie name		mean frequency [kHz]	duration [s]	start point [kHz]	end point [kHz]	min frequency [kHz]	max frequency [kHz]
Bottlenose dolphin [14]	mean	9,485	0,71	8,886	8,612	6,421	12,719
	SD	2,337	0,4	3,157	3,47	1,684	3,949
Risso's dolphin[14]	mean	10,877	0,65	11,75	11,877	8,287	14,652
	SD	2,35	0,36	3,929	3,522	2,027	3,27
Striped dolphin[14]	mean	10,906	0,73	9,994	11,819	7,868	15,163
	SD	2,116	0,35	4,039	3,797	1,843	3,611
Common dolpin[14]	mean	10,475	0,47	10,912	11,919	8,527	13,149
	SD	1,827	0,29	3,526	2,9	1,942	2,696
Atlantic spotted dolphin[15]	mean	10,9	0,44	-	-	7,1	14,5
	SD	2	0,3	-	-	1,5	2,5
Short-beaked common dolphin[13]	mean	11,91	0,62	11,96	12,08	9,61	14,53
	SD	2,17	0,349	3,41	3,21	2,19	3,13

Table 3Whistle parameter table for pacific region section

Specie name		Duration [s]	Start point [kHz]	End point [kHz]	Minimum frequency [kHz]	Maximum Frequency [kHz]
Bottlenose dolphin[16]	Value	1,4	11,2	9	7,4	17,2
	SD	0,7	4,6	3,7	2,2	3,1
Short-beaked common dolphin[16]	Value	0,8	9,8	11,4	7,4	13,6
	SD	0,4	3,9	3,9	2,3	3,4
False killer whale[16]	Value	0,4	5,2	5,8	4,7	6,1
	SD	0,2	2,2	1,5	1,2	1,5
Pantropical spotted dolphin[16]	Value	0,9	9,5	15,3	8,2	18,7
	SD	0,4	2,9	5,2	1,7	3
Long-beaked common dolphin[16]	Value	0,7	10,1	14,1	7,7	15,5
	SD	0,4	3,9	4,5	2,2	4,2
Short-finned pilot whale[16]	Value	0,4	4,4	5,5	3,6	6,1
	SD	0,3	3,1	4,3	2,3	4,2
Rough-tooth dolphin[16]	Value	0,6	6,8	8,5	6,3	9,1
	SD	0,4	2,9	3,1	2,5	3
Striped dolphin[16]	Value	0,8	10,2	12	8,1	14,8
	SD	0,3	3,7	2,8	1,6	3,5
Spinner dolphin[16]	Value	0,6	10,4	12,4	9,1	13,7
	SD	0,4	3,4	3,6	2,5	3,5
Pacific Fraser's dolphin[17]	Value	0,46	11,9	13,9	11	14,9
	SD	0,7	2,9	3,5	2,3	0,23
Irrawaddy dolphin[18]	Value	0,2	4,5	4,1	3,2	4,2
	SD	0,02	2,6	2,1	1,2	1,1
	Value	0,3	4,3	3	3,1	4,2
	SD	0,01	1,7	1,3	1,4	1,4

In order to find and extract specific features of whistles produced by a particular specie, it is reasonable to present the above parameters in a graphical way in order to compare them. It is not always easy to extract some characteristic features from obtained data. Moreover, if there will be a sufficient amount of whistle samples that will be taken to analysis, it will be possible to use the following graphs for the classification process.

All of the comparison graphs of whistle parameters are included in [*Appendix 1*].

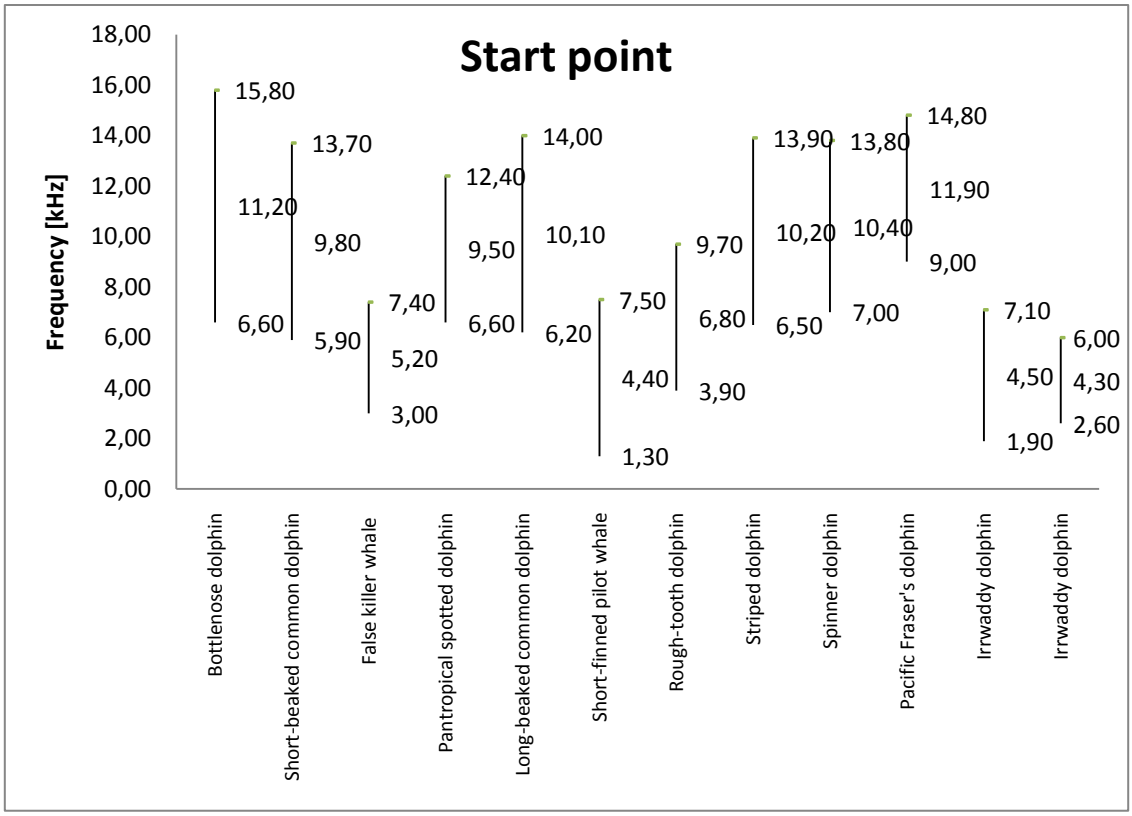


Fig. 7 Whistle start point values with their SD values considered of Pacific region section

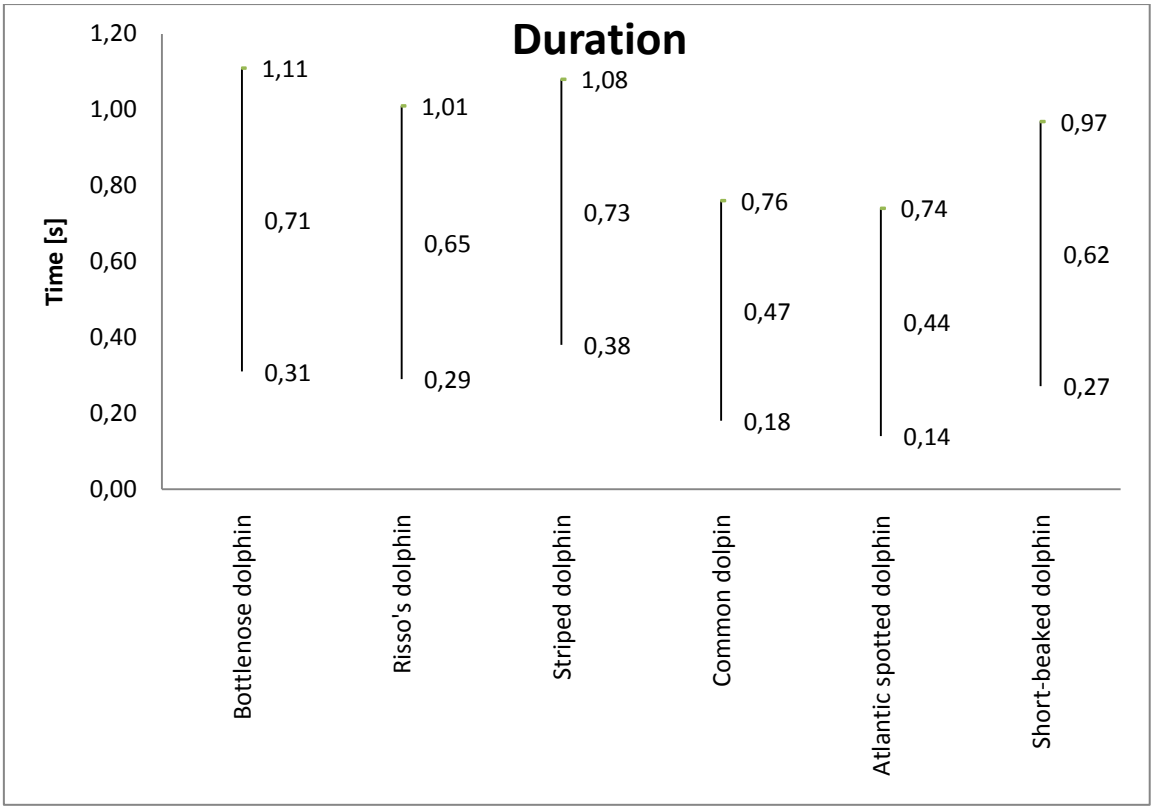


Fig. 8 Whistle duration values with their SD values considered of Atlantic region section

2.2.3 Geographic location research

Another useful tool for further analysis was the geographic location table, this contains information about the abundance of a given specie. This research is important as the LAB's patterns of dolphin whistles are recorded in a variety of oceans and seas. It is also reasonable to compare those locations with the areas from which come whistles that were taken into consideration in the previously presented tables. Because dolphins of the same species, living in two distinct places are producing whistles of different parameters, such comparison was prepared in [*appendix* 2]. An example of this is presented in the following figures *(fig.9. and fig.10)* showing the geographic location of Bottlenose dolphins and the research area in which the data was collected by researchers.

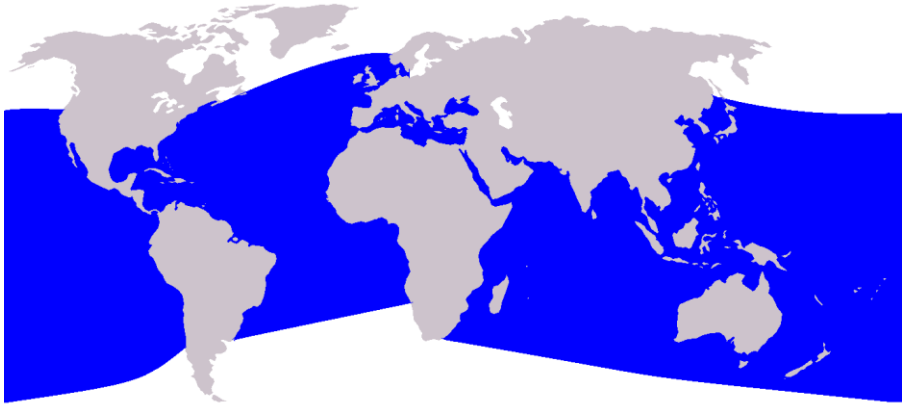


Fig. 9 Bottlenose dolphin abundance marked in blue color.

Fig. 10 Whistles of bottlenose dolphins taken into account were recorded in the tropical Pacific Ocean (marked above in orange)

2.2.4 Sources used in the research section

Many sources were used in the research phase, such as: LAB, SeaWatch Foundation, University of Bangor, Groupe de Recherche sur les Cétacés, Scripps Institution of Oceanography, University of California at San Diego and many others. Documents in which the parameters of whistles were found are presented in the tables below.

Table 4 Reference table for the Atlantic region section

Specie name	Reference link	Author	Title	Year
Bottlenose dolphin	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04786982	Alexandre Gannler, Sandra Fuchs, Odlle Gannler, Julle N. Oswald	Pelagic Delphinids of the Mediterranean sea have different whistles	2008
Risso's dolphin	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04786983	Alexandre Gannler, Sandra Fuchs, Odlle Gannler, Julle N. Oswald	Pelagic Delphinids of the Mediterranean sea have different whistles	2008
Striped dolphin	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04786984	Alexandre Gannler, Sandra Fuchs, Odlle Gannler, Julle N. Oswald	Pelagic Delphinids of the Mediterranean sea have different whistles	2008
Common dolpin	http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04786985	Alexandre Gannler, Sandra Fuchs, Odlle Gannler, Julle N. Oswald	Pelagic Delphinids of the Mediterranean sea have different whistles	2008
Atlantic spotted dolphin	http://oceanwidescience.org/PDF/JASA%20Lammers%20et%20al%20%282003%29.pdf	Lammers MO Au WWL and Herzing DL.	The broadband social acoustic signaling behavior of spinner and spotted dolphins	2002
Short-beaked common dolphin	http://www.seawatchfoundation.org.uk/docs/Griffiths2009_SBCDwhistle%20repertoire.pdf	Emily T. Griffiths	The repertoire analysis of the short-beaked common dolphin, *Delphinus delphis*, from the Celtic Deep and the Eastern Tropical Pacific Ocean	2009

Table 5 Reference table to the Atlantic region section

Specie name	Reference link	Author	Title	Year
Bottlenose dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Short-beaked common dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
False killer whale	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Pantropical spotted dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003

Long-beaked common dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Short-finned pilot whale	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Rough-tooth dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Striped dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Spinner dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald.pdf	Julie N. Oswald, Jay Barlow, Thomas F. Norris	Acoustic identification of nine delphinid species in the Eastern Tropical Pacific Ocean	2003
Pacific Fraser's dolphin	http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Oswald%20et%20al%202007%20Frasers.vocals_Bioacoust2.pdf	J.N. OSWALD, S. RANKIN AND J. BARLOW	First description of whistles of Pacific Fraser's dolphins, *Lagenodelphis Hosei*	2007
Irrwaddy dolphin	http://lib.ioa.ac.cn/ScienceDB/JASA/jasa2000/pdfs/vol_108/iss_4/1938_1.pdf	Sofie M. Van Parijs, Guido J. Parra and Peter J. Corkeron	Sounds produced by Australian Irrawaddy dolphins *Orcaella brevirostris*	2000

2.3 Whistle classification

The second section of the bioacoustic analysis was the computer analysis of dolphin whistles. At first it was assumed that sounds would be analysed in an already existing software that was available online. Unfortunately, no such program was found and a new code was created in Matlab 7.10.0 (R2010a) for recognition and extraction of whistles. The task of this code was to extract from whistle samples the parameters as presented in the research section, i.e. duration, mean frequency, minimum and maximum frequency, start and the end point. In comparing those parameters with the previously prepared tables, it was possible to classify the whistle to the individual specie which potentially produced it.

2.3.1 Procedure

Whistles selected for the analysis were chosen from the LAB's recording collection, this consists of a variety of underwater sound samples from the Ligurian Sea. Not all of the recordings contained whistle patterns; they also contained sonar patterns or other noise most likely caused by shipping. The first step was to choose and extract whistles which had quite a strong signal from LAB's recordings, in order to carry further analysis out efficiently. For this purpose Adobe Audition software was used, this returned whistle samples in a wav file that could be directly analysed in Matlab.

Secondly a spectrogram was created to show the graphical relation between time and frequency of the whistle. This was created using matlab software. The Spectrogram command extracted directly from the wav file variables such as: time, frequency and power spectral density (PSD). The last parameter simply indicates how strong the signal is in a given range of frequency, or time. The spectrogram also shows an image of the wave pattern, in this case whistle pattern, from which all parameters can be more or less accurately read.

Next the whistle was extracted from all of the other sounds that were present in the sample. In order to obtain a clear, extracted whistle, frequency was limited from 4 kHz to 20 kHz, which is the frequency range of whistles. In this range the highest local maxima of PSD values in each time domain were extracted corresponding to the frequency of the whistle returning as plot of the frequency in time domain, what was the whistle.

The final step was to estimate and fit the whistle contour so as to receive the values of frequency and time to be used for further classification. This classification process was based on the comparison of the received parameters of the extracted whistles and their comparison with the values in the parameter tables[19].

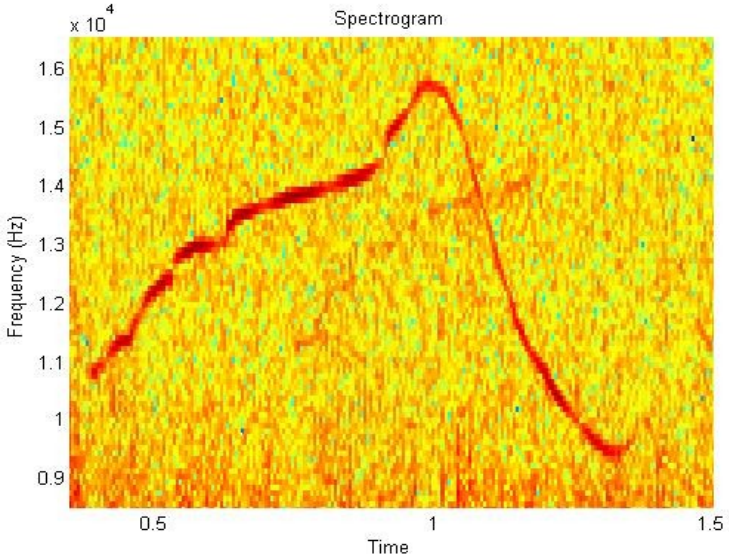


Fig.11. shows a spectrogram of sound sample, the red contour represents the whistle. The more intensive the color is the stronger the value of the (PSD). In this case the whistle signal is very strong and the whistle is not destructed by other sounds.

Fig. 11 Whistle spectogram

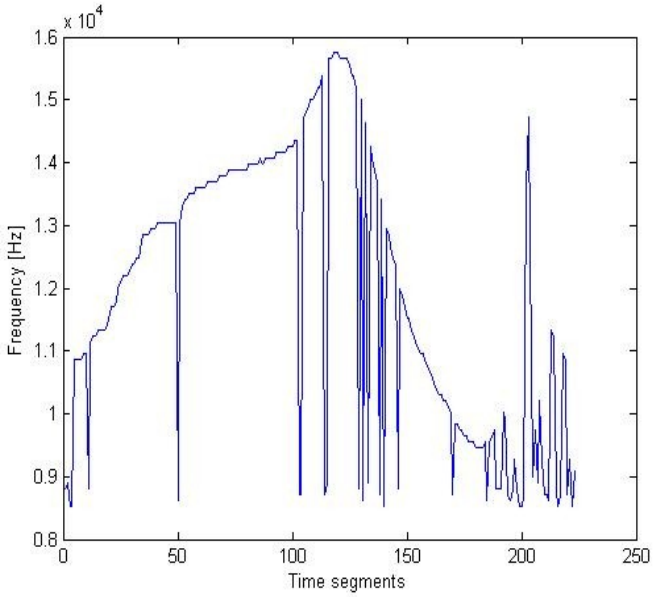
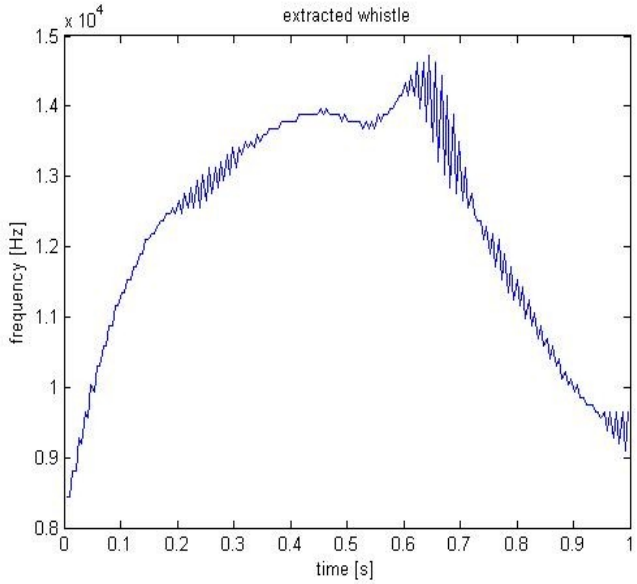


Fig. 12 shows the whistle after extraction. Values of the frequency corresponding to the highest local maximum value of the PSD was extracted and plotted in time segments. Such extracted whistle still have to many brakes and has to be fitted to produce a continuous line representing the whistle contour.

Fig. 12 Whistle extraction



Finally, the Fig. 13 represents the estimated and fitted contour of extracted whistle.

Fig. 13 Whistle estimated contour

2.3.2 Results

From a total of ten whistles analysed only two were of adequate quality in order to perform whistle extraction. This is because nearly all samples contained unwanted sounds or simply noise in the frequency range of the whistle. Such noise makes it impossible to carry out the extraction of the whistle and as a result the extracted pattern is that of the noise (Fig.14). Another fact that influences the analysis could be the strength whistle signal which in itself was relatively low.

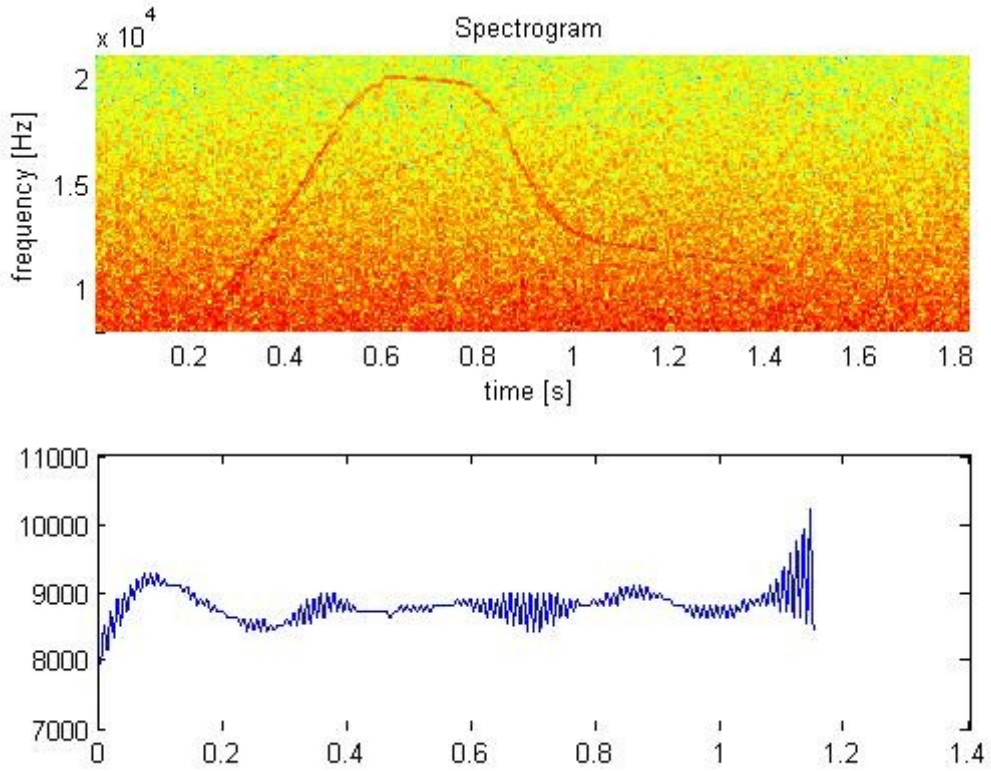


Fig. 14 Figure at the top is an example of a sample, which cannot be analysed. Because of too many sound waves in the frequency range of a whistle, it makes it impossible to extract the whistle. The red color in the bottom of spectrogram indicates frequency ran

From the two whistle samples that gave relatively positive results the whistle contour was extracted and also frequency and time parameters of whistle were received, i.e. duration, mean frequency, minimum and maximum frequency and the start and end point. Extracted whistle contours and the parameters are given in the following table.

Table 6 Parameters received after analysis of the first whistle

parameter	value
Duration [s]	1,0
Mean frequency [kHz]	11,9
Start point [kHz]	8,4
End Point [kHz]	9,0
Minimum frequency [kHz]	14,7
Maximum frequency [kHz]	8,4

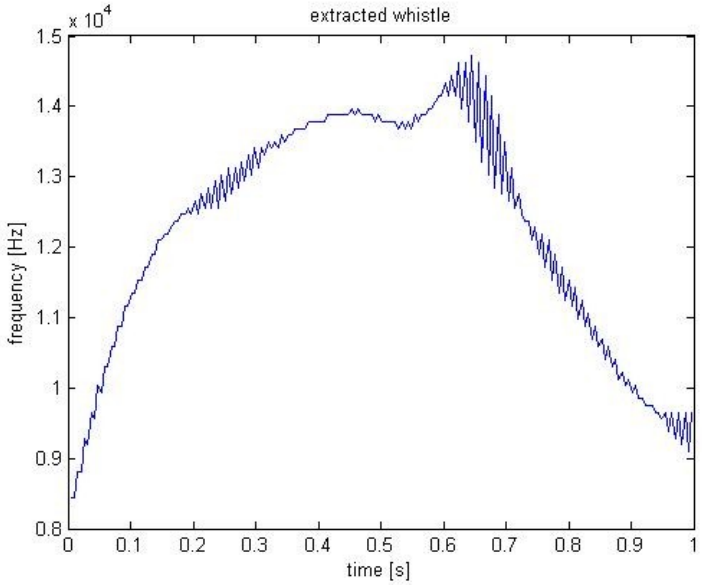


Fig. 15 First extracted whistle contour

Table 7. Parameters received after analysis of the first whistle

parameter	value
Duration [s]	0,6
Mean frequency [kHz]	9,2
Start point [kHz]	10,9
End Point [kHz]	10,4
Minimum frequency [kHz]	8,2
Maximum frequency [kHz]	10,9

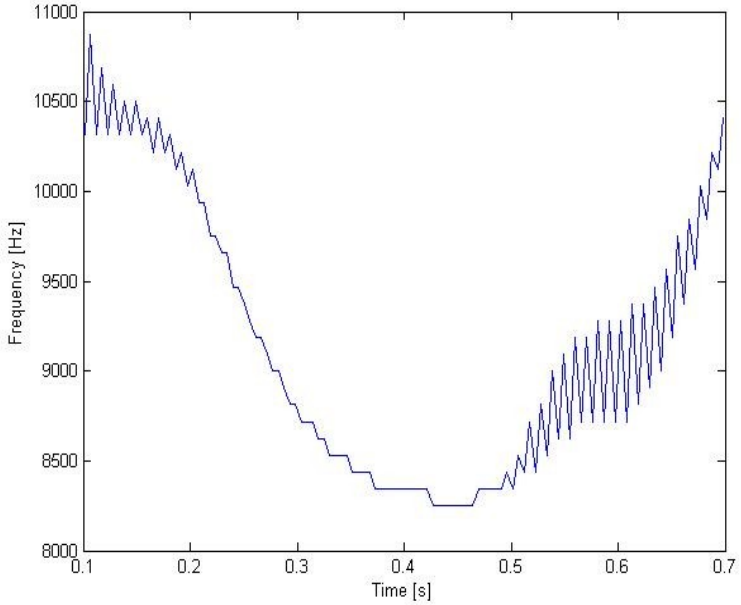


Fig. 16 Second whistle contour extracted

2.3.3 Classification

Analysed samples were recorded on the Ligurian Sea, this falls into the Atlantic region section of the research part. Using the table and the graphs previously prepared two of the extracted whistles were classified.

The first whistle was classified to a possible three species i.e.: Striped dolphin, Risso's dolphin and the short-beaked common dolphin. All of the parameters fit within the specified ranges presented in the graphs, which suggests that this whistle was produced by one of those three species.

2.4 Conclusions

Dolphins produce sounds mainly for communication between individuals as well as for echolocation, amazing ability to detect objects underwater. Besides they also use sounds to express their emotions i.e. when they are stressed, frightened, angry. By analyzing those sounds we can learn not only about their behaviours, but also how man-made sounds are affecting their life. All of those sounds vary in ranges of frequency and the way, that are produced. Whistles mainly have frequency ranges from 4 kHz to 20 kHz and their duration is close to 1 s, whereas clicks are sounds of much high frequency, sometimes reaching values greater than 100 kHz and they consists of sequences, called click trains. Burst sound pulses are the sounds generally regarded as cries, barks, grunts and they are audible for humans. It is quite easy to distinguish those sounds from each other; however it is difficult when a given sound has to be classified to potential specie that could produce it.

In the research section of the bioacoustic part of the project, all the necessary information was efficiently collected, in order to carry out further classification in an effective way. From a total of thirty seven species, thirteen species were taken into consideration and included in the analysis. The research section was divided into two categories (Pacific and Atlantic region), this was necessary because dolphins of the same specie living in different, distinct areas produce different whistles. Six of the the most important parameters were extracted and gathered in the relevant parameter tables. These parameters are: duration, mean frequency, minimum and maximum frequency, start and end point. Another useful tool for further classification was the geographic location tables containing information about the areas of abundance of given specie.

All six species included in the Atlantic region section seem to produce very similar whistles. However, in comparison with other species, bottlenose dolphins have got the longest duration values and the lowest values of frequencies, i.e. mean frequency, minimum frequency, start and end point. Mean value of the maximum frequency is also very low, but its standard deviation is relatively high, this makes the range of the

maximum frequency quite wide. Also Atlantic spotted dolphins and Common dolphins tend to have the shortest values of duration, but as for frequency parameters, they are all comparable with the ranges of other species.

As for the whistles produced by eleven dolphin species included in the Pacific region section, many more characteristics can be found. Irrwaddy dolphins tend to have very short values of duration and their standard deviation values are extremely small. This states that Irrwaddy dolphins' whistles have got a fixed duration of 0,2 s for first whistle type and 0,3 s for the second. These whistles also have got very low frequencies which makes them easy to differentiate from other species. Another characteristic of such dolphins is their abundance, they live only in limited areas close to the northern part of Australia. Another dolphins, which whistles seem to be unique, are Short-finned dolphins, which behavior is more similar to whales rather than dolphins [*20*]. The frequencies of their whistles appear to be very low and the time of duration is also relatively low. Also whistles produced by Bottlenose dolphins have got some unique characteristics, i.e. the longest duration time. Whistle parameters of false killer whales have got very small standard deviation values, resulting in small ranges of their frequencies as well as ranges of duration. Pantropical spotted dolphins' whistles have the highest values of the end point and maximum frequencies. Another specie with identifiable whistle characteristics is the Pacific Fraser's, their whistles have got the highest value of minimum frequency and a very small range of maximum frequency.

In conclusion, in the Atlantic region, characteristic whistles are those produced by Bottlenose dolphins. Also Common dolphins and Atlantic spotted dolphins produce quite characteristic whistles, but they are not as unique as those of Bottlenose dolphins. In Pacific region, characteristic whistles are produced by: False killer whales, Irrwaddy dolphins, Bottlenose dolphins, Shot-finned dolphins, Pantropical spotted dolphins and Pacific Fraser's dolphins.

Unfortunately, not all dolphins produce unique whistles what makes the classification process relatively hard to perform. Very often one sample of whistle is not enough to classify whistle to a specie, because the parameters extracted can be imprecise. This is why a larger amount of whistles should be analysed and then taken for further process of classification. The results of whistle computer analysis shows that it is not possible to extract whistles from all samples. From a total of ten samples it was possible to extract only two whistles, what states only 20% of samples analysed. The efficiency of the process is so low, because many whistle samples contained a lot of noise in the frequency range of the whistle. In such cases it was impossible to extract whistles from those samples, as the only pattern extracted was that of the present noise. Moreover some whistles contained many brakes what also resulted in some problems in their extraction, especially with the estimation of the whistle contour shape and structure.

Also the strength of the whistle signal influence its analysis. The lower the signal was, the harder the extraction was.

In conclusion, for efficient analysis and classification whistle samples have to be strong, clear and they cannot contain any noise in the frequency range of the whistle. The best way is to record whistles in some areas of limited noise level, what is quite hard, because of the appearance of many man-made sounds like shipping.

3. CAD Simulation

3.0 Aim

The aim of the CAD simulation task is to further advance the current state of the simulation project. The buoy has been drawn in CAD (Solidworks) by the 2009 EPS team however to date no simulations have been performed. The buoy will be simulated using CAD software in order to assess its behaviour within the marine environment.

3.1 Research

3.1.1 Environment

The ocean environment is one of varied conditions. The buoy must be able to withstand any of these which do not fall outside 'the norm'. This includes wind speeds, sea currents, waves and of course normal weather elements such as Sun and Rain[71,75]. The buoy's stability should be adequate to survive full ocean storms even when the buoy will be used primarily in the near –coastal marine environment as this will increase its usability.

3.1.2 Consequences

Short circuits, leakage currents and high voltage flash-over will occur if water comes into contact with the electric circuit in the buoy. This will cause the buoy to fail. The buoy may suffer permanent damage or at the very least be unable to record sound for a period of time. Therefore it is important to ensure that not only the hub is fully insulated giving the components protection from wave splashes but also that the buoy will not become overturned or submerged.

3.1.3 Simulations

In order to progress with the project it is important to establish exactly what will need to be simulated and what information/facilities are required to do this.

- Waterline – Exact size and mass must first be calculated
- Stability – in terms of theoretical formulae – requires accurate weight of components – effect of different masses on this.
- Angle of vanishing – Point at which the buoy can tip and still right itself – effect of mass / weight distribution.
- Aerodynamics – This will affect tow speed.
- Structural stability. Testing the buoy under stresses and strains.

3.1.4 Software

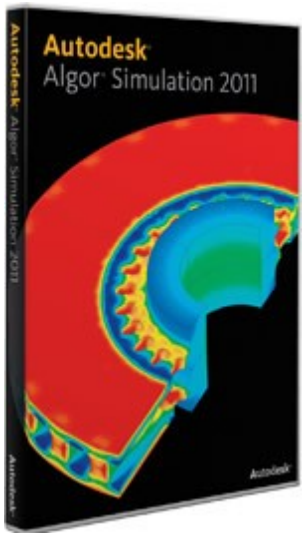
Before starting the simulation an appropriate software package has to be found. Software packages will be evaluated on the basis of features, user friendliness and finally availability.

Table 7 Software packages evaluation

Name of Software	**Key features**	**Evaluation**	**Available**
Solid works	• Complex Geometry and Freeform Surface Creation • Feature Recognition • Reverse Engineering • Motion Analysis • Structural Validation • Environmental Impact Evaluation • Design for Manufacturability • Fluid Flow Simulation • Photorealistic Rendering.[63]	Exact properties and dimensions can be defined but school does not have plug-in to do simulations. However plug-in in itself is limited as it does not have all of the required simulation capabilities to simulate the AAB.	✓
Ansys	• Analysis of materials. • Interactive GUI • Integrated response of fluids, structures and materials.[64]	School only has simple version which does not contain enough functionalities to carry out buoy simulation.	✓
NX	• Linear and nonlinear stress, vibration, motion, dynamic response, durability, flow and thermal analysis • Integrated multi-physics solvers • Model preparation with multi-CAD support • PLM integration with advanced simulation structure management [65] • Open application and system support	Developed by Siemens corp - school has this software available. However it has limited functions which could prove troublesome in later more advanced simulation. Fluid dynamics are also not included. Schools version is also in Spanish which presents me with an added difficulty.	✓
Autodesk ® Algor®	• CAD support. • Modeling and meshing • Static stress and linear dynamics • Mechanical event	Has more functions than other available software (including Fluid dynamics) & can be downloaded legally at no extra cost.	✓

	simulation • Computational fluid dynamics (CFD) simulation • Multiphysics [66]		
Ansys Professional or student with Ansys Ls-Dyna or Ansys Autodyn	• Integrated response of fluids, structures and materials. • Multiple solvers, including those for structural analysis and fluid flow. • Analysis of materials. • Interactive GUI • Simulation integration • Extensive material model library[67]	Capable of performing fluid dynamic (wave) simulations. These are the preferred options but are very expensive.	✘
Adina	• Stress analysis of solids (2D and 3D) • Analysis of structures in statics and dynamics. • Linear or nonlinear analysis including the effects of material nonlinearities, large deformations and contact conditions.[68]	From watching videos on YouTube it is possible to conclude that Simulations are more complex and time consuming to perform in Adina than in Ansys. Adina is available as freeware on the internet however a version of this software was downloaded onto my laptop but failed to install correctly.	✘
Catia V5	• Linear stress analysis on parts and hybrid assemblies • (solid, surface, and wireframe) • Transient and harmonic dynamic analysis • Contact analysis • Buckling analysis • Thermo-mechanical analysis • Modal analysis • Vehicle assembly analysis • Assembly of multiple analysis models.[69]	Catia is very advanced and therefore expensive software. It is primarily used in the automotive industries.	✘

3.2 Chosen Solution



"Autodesk® Algor® Simulation software, part of the Autodesk® solution for Digital Prototyping, provides a range of mechanical simulation tools to help designers and engineers make decisions earlier in the design process. Support for multi-CAD environments and extensive finite element modeling tools help manufacturers study initial design intent and accurately predict product performance. Autodesk Algor Simulation allows you to validate and optimize designs before manufacturing—increasing efficiency, minimizing reliance on physical prototypes, reducing costs, and decreasing errors." [72]

- **CAD support—**Direct, associative data exchange with most CAD software. (Including Solidworks)
- **Modelling and meshing—**Create finite element models and meshes using tools and wizards designed to improve productivity and simulation accuracy.
- **Static stress and linear dynamics—**Study structural response of designs.
- **Mechanical event simulation—**Enhance design decisions by using multi-body dynamics with support for large-scale motion, large deformation, and large strain with body-to-body contact.
- **Computational fluid dynamics (CFD) simulation—**Study thermal characteristics of designs and perform accurate, detailed fluid flow analysis.
- **Metaphysics—**Study multiple physical factors acting simultaneously by combining results from different analysis types.

3.2.1 Limitations

Finding appropriate software has been extremely time consuming & a compromise has had to be made due to the timescale of the project. The chosen software is limited as it is not able to perform all of the required simulations as detailed in the simulation section.

3.2.2 Solution to Limitations

Due to a lack of available software in the school S/W is not available to me that has all of the required functions to complete the simulation task. We have therefore broken down the task into several subtasks in order to find ways of carrying out each part of the task.

Table 8 Work process

Factors to be tested	Test method
Waterline – Exact size and mass must first be calculated	Tested using formulae
Stability – in terms of theoretical formulae – requires accurate weight of components – effect of mass on this	Tested using formulae
Angle of vanishing – Point at which the buoy can tip and still right itself – effect of mass / weight distribution	Tested using formulae.
Buoyancy - Buoyancy concerns the Archimedes Principle, in other words Will it Float? The buoyancy force is the upward vertical force felt by a submerged, or partially submerged body. It is equal to the weight of the fluid displaced by the submerged portion of the body. A body will sink until the buoyancy force is equal to the weight of the body. [73]	Tested using formulae.
Aerodynamics – This will affect tow speed	Tested using CAD software Autodesk Algor Simulation Professional 2011
Structural stability. Testing the buoy under stresses and strains.	Tested using CAD software Autodesk Algor Simulation Professional 2011

3.3 Further Research

3.3.1 Formulae

As the buoy closely resembles a boat in shape the following formulae's (usually used in boat design) will be used in order to calculate the behavioural properties of the buoy.

Table 9 Formulas used in calculation process

Factor	Formulae
Waterline – Exact size and mass must first be calculated	submerged volume == total displacement / density of water density of water == 62.5 lb/ft^3 fresh or 64 lb/ft^3 salt[73]
Stability – in terms of theoretical	Capsize Screening Formula = Beam /

formulae – requires accurate weight of components – this will be effected by buoy weight	$(\text{Displacement} / 64)^{1/3}$ (Displacement is in Pounds Beam is measured in Feet)[76]
Angle of vanishing – Point at which the buoy can tip and still right itself.	Screening Stability Value (SSV) = $(\text{Beam}^{2}) / (\text{BR} * \text{HD} * \text{DV}^{1/3})$ BR: Ballast Ratio (Keel Weight / Total Weight) HD: Hull Draft DV: The Displacement Volume in cubic meters. DV is entered as pounds of displacement on the webpage and converted to cubic meters by the formula: Displacement Volume in Cubic Meters = (Weight in Pounds / 64)*0.0283168 Angle of Vanishing Stability approximately equals 110 + (400 / (SSV-10))[77]
Buoyancy - Will it Float?	Assuming full submersion Force of Buoyancy (F_B) = Vol x g_W [78]

3.4 Theoretical calculations

Formulas that are commonly used in boat design are typically expressed in imperial format. In order to use these formulas accurately but also produce relevant and analysable results I will be converting metric data from the buoy into imperial to carry out the calculations before converting it back to analysable metric data.

Data calculated by Autodesk Algor Software *[appendix 3]* and from technical drawings produced in Solidworks will be used to carry out the theoretical calculations (formulae as detailed in the research section).

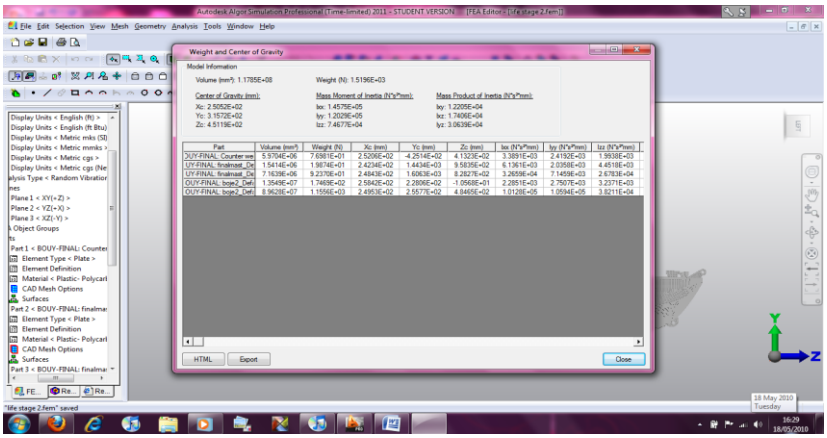


Fig. 17 Autodesk Algor datasheet production

3.4.1 Submerged volume

Submerged volume = total displacement / density of water
density of water == 62.5 lb/ft^3 fresh or 64 lb/ft^3 salt

1pound = 4.44822162825N ***So*** 1519.6 Newton's = 341.61966893638277 Pounds

341.61966893638277/64 = $5.34ft^3$

3.4.2 Capsize Screening Formula

Capsize Screening Formula = Beam / (Displacement / 64)$^{1/3}$

(Displacement is in Pounds, Beam is measured in Feet)

The weight of the boat used in the calculations is taken from data produced from the autodesk algor software. This is without any extra weight used to enhance the stability of the buoy.

1200mm = 3.937007874012 ft

1519.6 Newton's = 341.61966893638277 Pounds

= 3.937007874012/(341.61966893638277/64) $^{1/3}$

= (3.937007874012/5.337807327) $^{1/3}$

= 0.737570248$^{1/3}$

= 2.25

A value >2 means that the buoy may not be stable, therefore the result shown above may means that the boat may be vulnerable to capsizing. As changing the shape of the buoy is not an option, changing the weight of the buoy will now investigated in order

to establish how the stability of the vessel is affected by this. It is also not an option to make the buoy lighter as the structure has already been manufactured.

Table 10 Effect of weight on buoy stability

Weight (N)	Mass (Pounds)	Capsize screening
1519.6	341.6196689	2.212710744
1779.289	400	1.88976378
2001.7	450	1.679790026
2224.111	500	1.511811024
2446.522	550	1.374373658
2668.933	600	1.25984252
2891.344	650	1.162931557
3113.755	700	1.079865017
3336.166	750	1.007874016
3558.577	800	0.94488189
3780.988	850	0.889300602
4003.399	900	0.839895013
4225.811	950	0.795690012
4448.222	1000	0.755905512

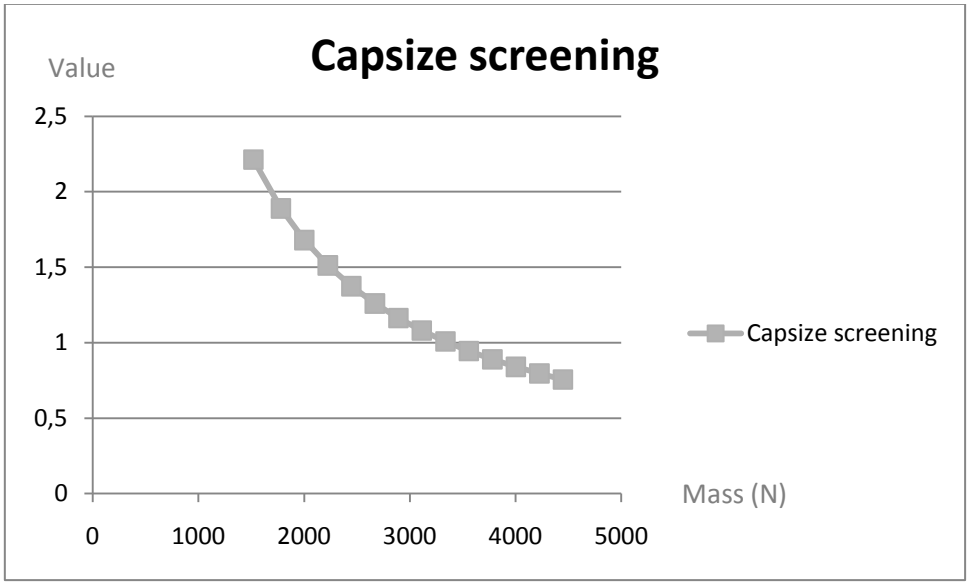


Fig. 18 Effect of weight on buoy stability

As the graph shows the more weight is placed within the buoy the more stable it will become.

3.4.3 The Angle of Vanishing

Screening Stability Value (SSV) = (Beam ^{2}) / (BR * HD * DV $^{1/3}$)

BR: Ballast Ratio (Keel Weight / Total Weight)

HD: Hull Draft

DV: The Displacement Volume in cubic meters.
Displacement Volume in Cubic Meters = (Weight in Pounds / 64)*0.0283168)
Angle of Vanishing Stability approximately equals 110 + (400 / (SSV-10))
Screening stability volume

$=(3.937007874012^2)/((25.23255569980232/341.61966893638277)*2*(341.619668936382/64)*0.0283168^{1/3}) =15.500031/(0.073861543*2*1.626963673)$

=64.4920733 (SSV)

Angle of vanishing stability =110 + (400/(64.49-10)) =117.3407965
This calculation will now be carried out for a range of different buoy weights. This will enable the effect of weight on the angle of vanishing stability to be analysed.

Table 11 Effect of weight on angle of vanishing stability

Weight (N)	Weight (Pounds)	Beam Sq	BR	HD	DV	SSV	AVS
1519.6	341.6196	15.49997	0.073862	2	1.626964	64.49182	117.3408
1779.288651	400	15.49997	0.063081	2	1.905	64.49182	117.3408
2001.699733	450	15.49997	0.056072	2	2.143125	64.49182	117.3408
2224.110814	500	15.49997	0.050465	2	2.38125	64.49182	117.3408
2446.521896	550	15.49997	0.045877	2	2.619375	64.49182	117.3408
2668.932977	600	15.49997	0.042054	2	2.8575	64.49182	117.3408
2891.344058	650	15.49997	0.038819	2	3.095625	64.49182	117.3408
3113.75514	700	15.49997	0.036047	2	3.33375	64.49182	117.3408
3336.166221	750	15.49997	0.033643	2	3.571875	64.49182	117.3408
3558.577303	800	15.49997	0.031541	2	3.81	64.49182	117.3408
3780.988384	850	15.49997	0.029685	2	4.048125	64.49182	117.3408
4003.399465	900	15.49997	0.028036	2	4.28625	64.49182	117.3408
4225.810547	950	15.49997	0.026561	2	4.524375	64.49182	117.3408
4448.221628	1000	15.49997	0.025233	2	4.7625	64.49182	117.3408

As the table shows the screening stability value and therefore angle of vanishing stability is not effected by a change in weight.

3.4.4 Buoyancy

Assuming full submersion Force of Buoyancy (F_B) = Vol x g_W

$F_B = (3.93700787401x2x1.5) \times 64$ lbs/ft^3

F_B = 755.9055 lbs = *342.87 kg*

Weight of Buoy (without component weight) = 341.62lbs = *154.96 kg*

The Force of Buoyancy is greater than the Weight of the Buoy meaning the Buoy will float.

3.5 Simulation using Algor

Autodesk Algor simulation was chosen to perform the theoretical CAD simulations. The Autodesk Algor Help Guide 2010 was used in order to become familiar with the software. It was also used for reference throughought this simulation task.

3.5.1 Importing the CAD model

In order for simulations to be carried out the existing CAD (Solidworks) model must first be imported into Algor simulation software. The online help guides were used to find instructions on how to do this.
The Algor simulation online help guide outlines three methods for importing Data[79]:
1) Copying the file across from other CAD software. This requires CAD software that created the model to be open & is advantageous as material properties allocated in previous software can also be transferred. This is not an option for the import of the buoy as Solidworks is not available on the same workstation as Algor.

2) Opening the file directly into Algor. In order to do this the file must be saved in one of the following formats:- ACIS Files, Autodesk AutoCAD*, Autodesk Inventor, Autodesk Inventor Fusion, Autodesk Mechanical Desktop, IGES Files, Rhinoceros 3D, STEP Files Stereolithography (STL) Files. This is the preferred method to import the Buoy data.

3) Importing the file as Wireframe IGES. This is more complex than importing a 3D model but is a backup method. The file is opened selecting *Wireframe IGES (*.igs, *.iges)* as *files of type.* If all the entities in each part lie in a single plane the entities in the part can be imported into a sketch by selecting the *Import as 2D objects* check box. If the model will be analyzed using 2D elements, it must be imported into the YZ plane. Activating the *Import into YZ plane* check box will translate the positive X axis in the IGES file to the positive Y axis in the sketch and the positive Y axis in the IGES file to the positive Z axis in the sketch.

The CAD model was successfully imported into Algor. This was done using the direct import method *(2) as detailed above.)* In solidworks the file was saved in the STEP format and then opened in Autodesk Algor. The initial import can be seen across.

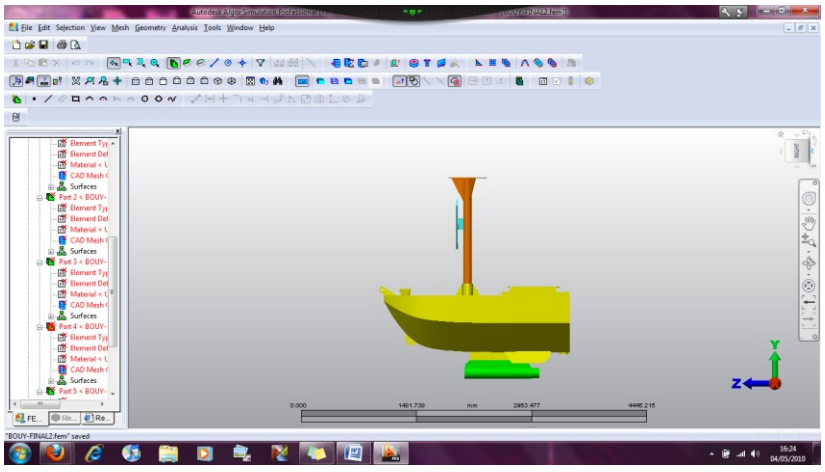


Fig. 19 Initial Buoy import

3.5.2 Creating a Mesh

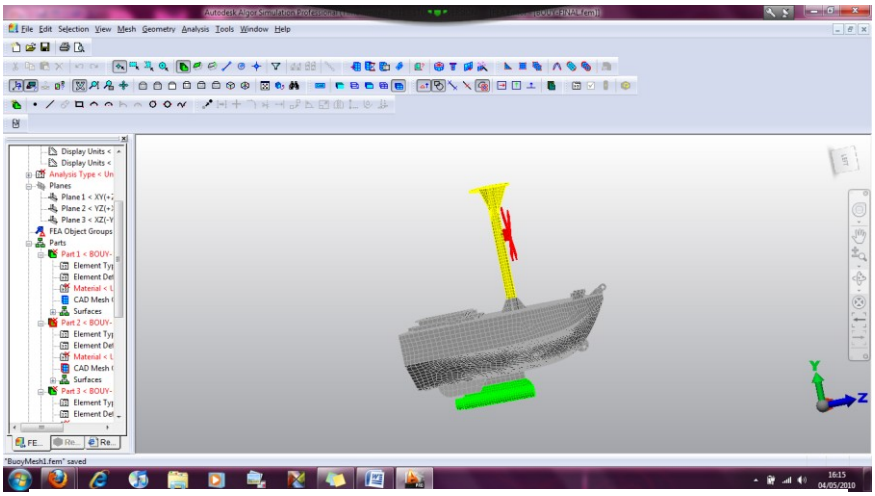


Fig. 20 Initial Mesh

Once the existing model had been imported into Algor the next step was to create a mesh structure. This is what will be used to carry out simulations on the buoy. The initial mesh structure was created by first knitting the assembly together and then using the mesh function. The result is shown to the left.

3.5.3 Assigning materials

The next step in the analysis is to assign the correct material types to each part of the buoy. It is important that this is done correctly as different materials will behave in different ways when placed under simulation conditions. The material used to manufacture the buoy is polyethylene, (10mm thickness for the body and 6mm for the shell.)

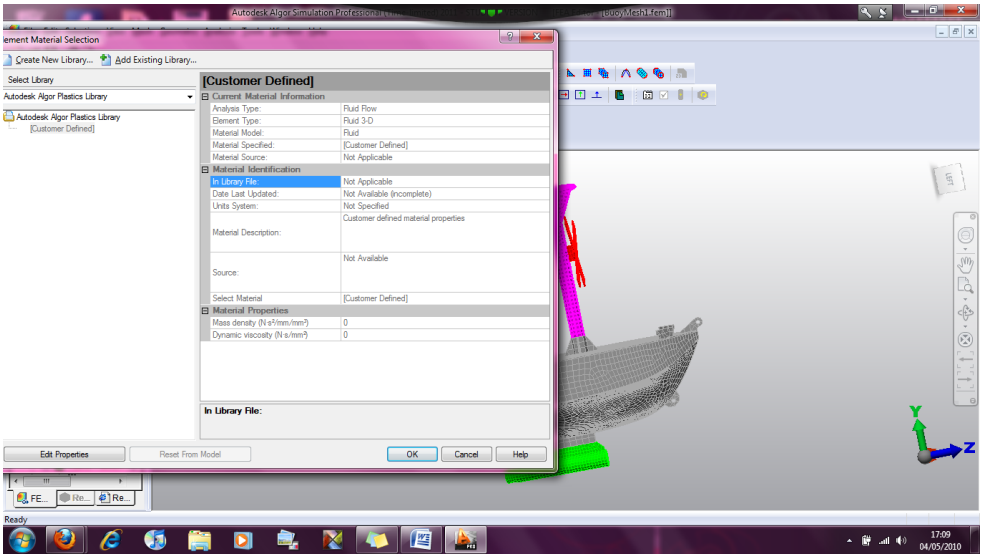


Fig. 21 Asigning materials

3.5.4 Unsteady fluid Flow Analysis

The first Analysis to be run on the buoy is unsteady fluid flow. This will monitor the behaviour of the buoy when it is on the water in the marine environment.

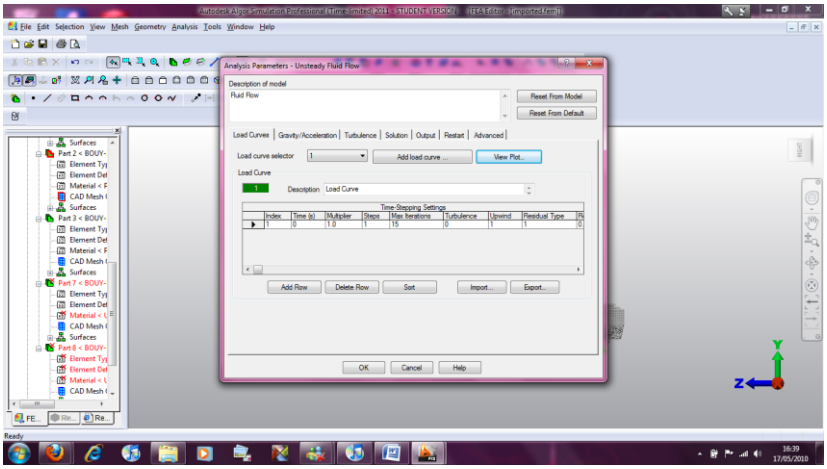


Fig. 22 Set test conditions

The first stage in the analysis was to set the test conditions (analysis parameters) a screenshot of this can be found in *fig.22*

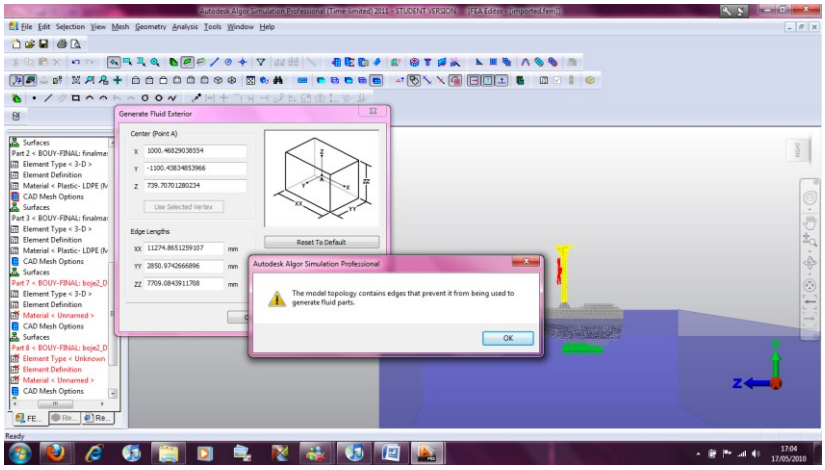


Fig. 23.Generate fluid exterior

The next step carried out was to generate the fluid exterior in order to simulate the marine environment in which the buoy was to sit. This process is illustrated in Fig. X. However this was unable to be created due to a problem with the model topology.

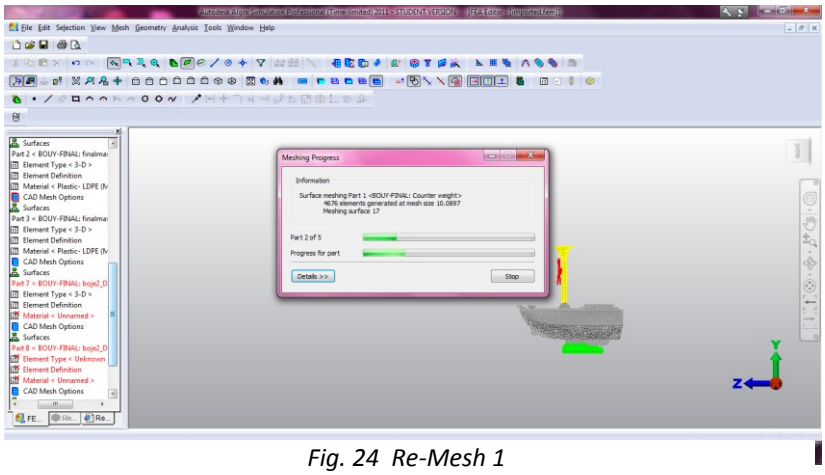
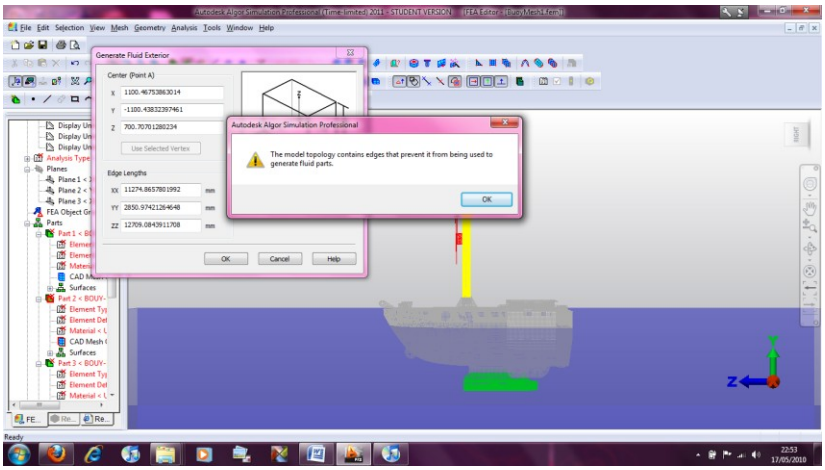


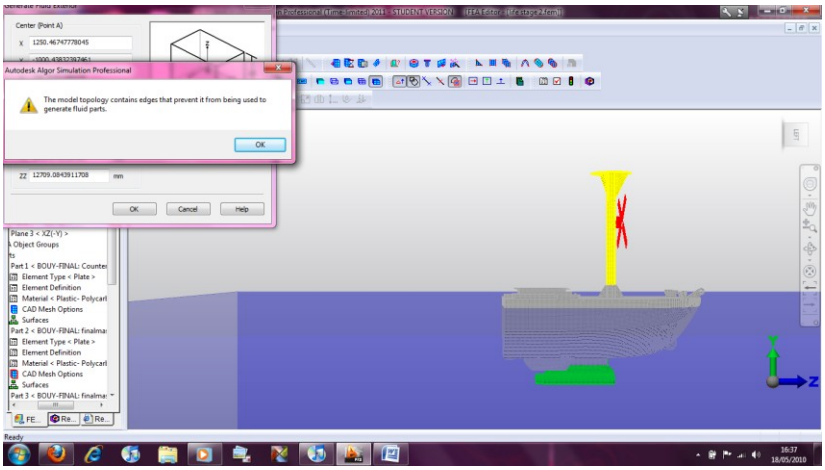
Fig. 24 Re-Mesh 1

The model was re-meshed in order to attempt to correct this problem.



The fluid exterior was still unable to be created due to the complex model topology.

Fig. 25Generate fluid exterior attempt 2



After creating a third mesh structure was created in order to troubleshoot the problem of creating the fluid. The same problem was again faced.

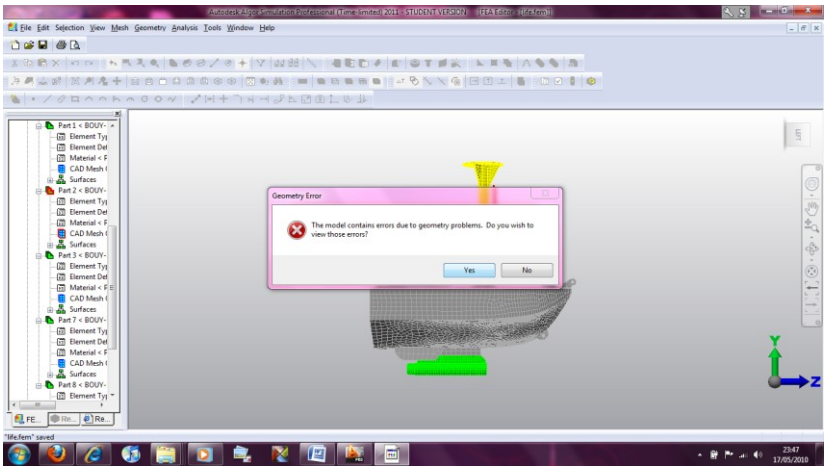
Fig. 26 Generate fluid exterior attempt 3

Due to the complex shape of the buoy difficulties have been faced in creating a stable analysis. A great deal of time has been spent troubleshooting within the Autodesk Algor software & the same problem is still faced regarding the model topology itself.

A further troubleshooting step would be to modify the Solidworks model. However this can only be done to a certain extent as the Buoy model must remain accurate in order to give useful simulation results. This simulation was put on hold in order to minimise wasted time and make efficient progress with the simulation task.

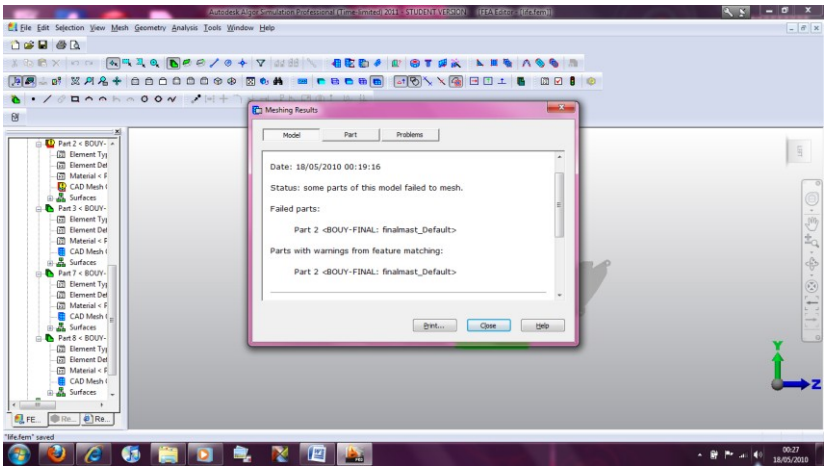
3.5.5 Static stress Analysis

The first Analysis to be run on the buoy is unsteady fluid flow. This will monitor structural analysis to be carried out.



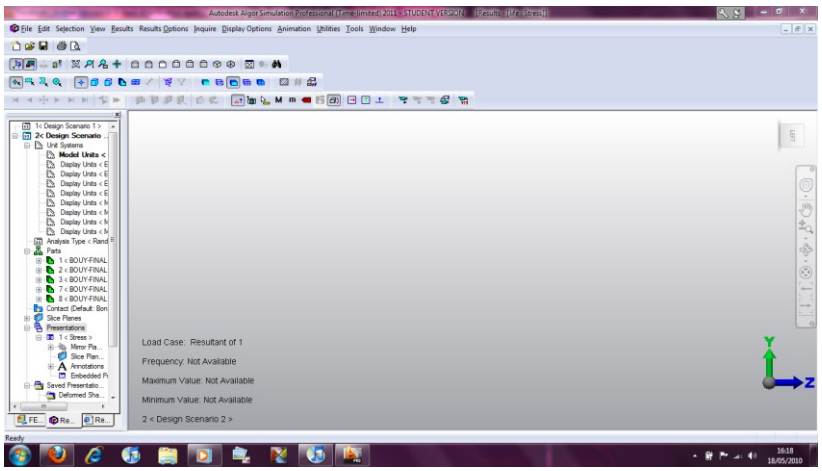
After setting the analysis parameters an analysis was run. This was unsuccessful as yet again the model topology was too complex to carry out the simulation.

Fig. 27 Static stress attempt 1



Troubleshooting dictated that the buoy was again re meshed. The mesh structure is important as different options work with different simulation types.

Fig. 28 re-meshing for static stress



Analysis was run for a second and third time. On the outset these analyses appeared to have functioned correctly however. No quantifiable results were produced.

Fig. 29.Failed static stress analysis.

3.5.6 Progress

All simulations carried out to this point have been unsuccessful. Using clues given by error messages flagged in Autodesk Algor software an appropriate troubleshooting step is to greatly simplify the solidworks model. This will allow the software to be tested. However it must be remembered that a heavily simplified model will not produce accurate & therefore useful simulation results.

3.5.7 Troubleshooting

As outlined in the progress section a much simplified representation of the buoy was created in order to test Autodesk Algor software. This was created using solidworks. The new model was then imported (in the same way detailed in section 3.5.1) into Autodesk Algor. Next the mesh structure was created.

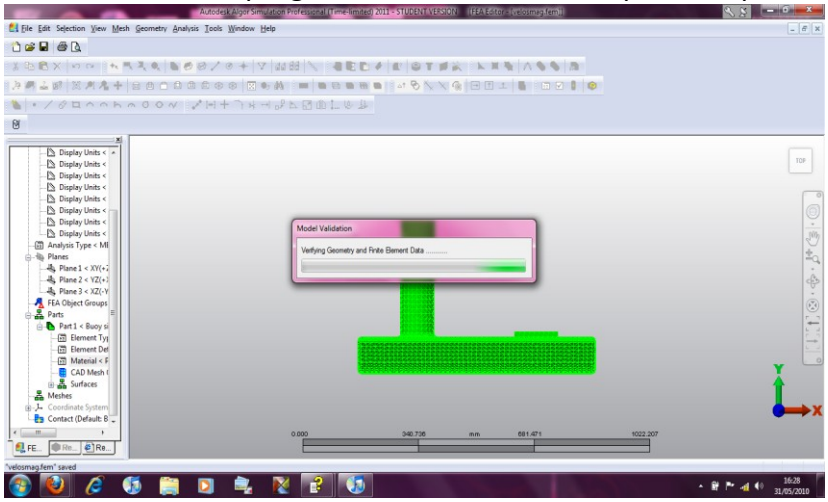
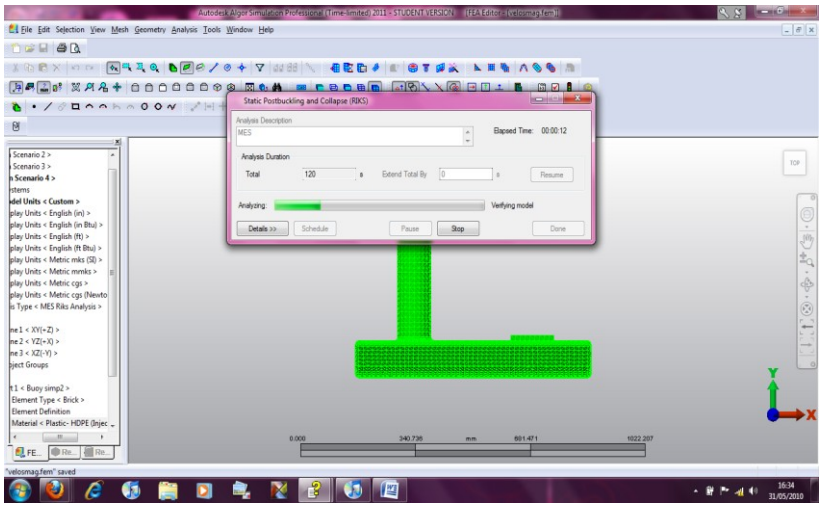


Fig. 30 Simplified meshed model



The parameters for Static stress (nonlinear material models) were set and the analysis was run. Visible results were produced from the analysis however quantifiable values were still not given from this type of analysis.

Fig. 31.Simplified meshed model

This simplified test shows that the software is functioning correctly and is able to carry out simulations. However it is also possible to deduce that thus far the incorrect types of calculations have been carried out in order to produce valuable results.

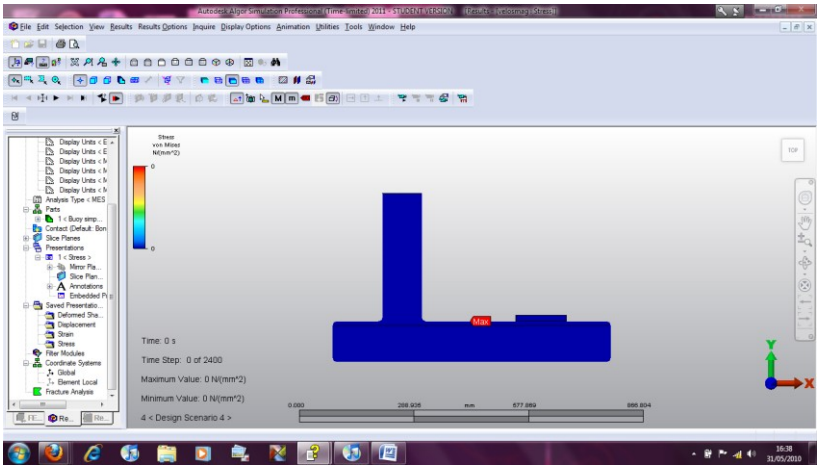


Fig. 32 Simplified model results

3.5.8 MES RIKS Analysis

MES RIKS analysis allows the weak/breaking points in the model to be identified. It also allows maximum stress levels to be ascertained regarding the physical properties of the buoy.

3.5.8.1 Operation

The parameters were first set and the analysis was run.

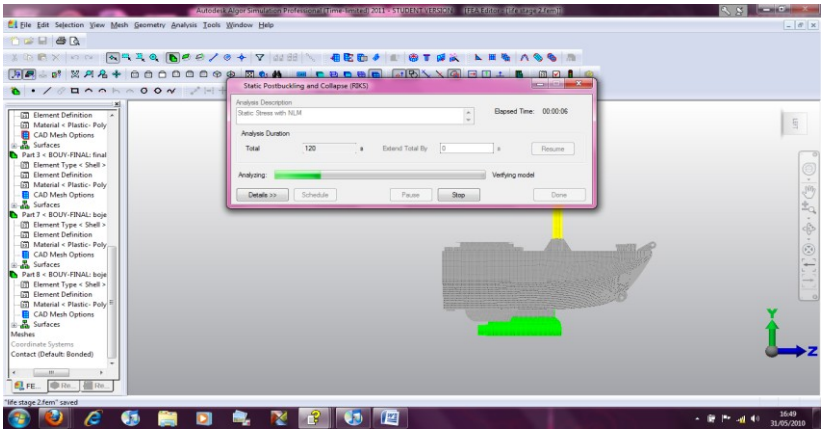


Fig. 33 Running MES RIKS analysis

Settings were changed to show the buoy under a variety of stresses and strains. From this images could be exported.

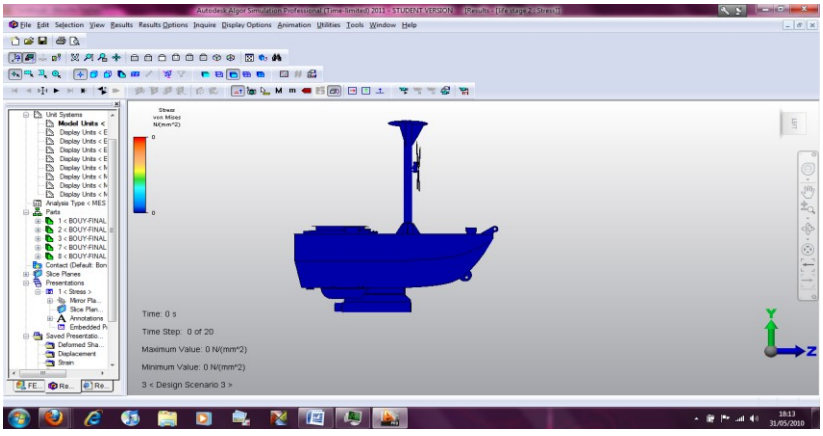
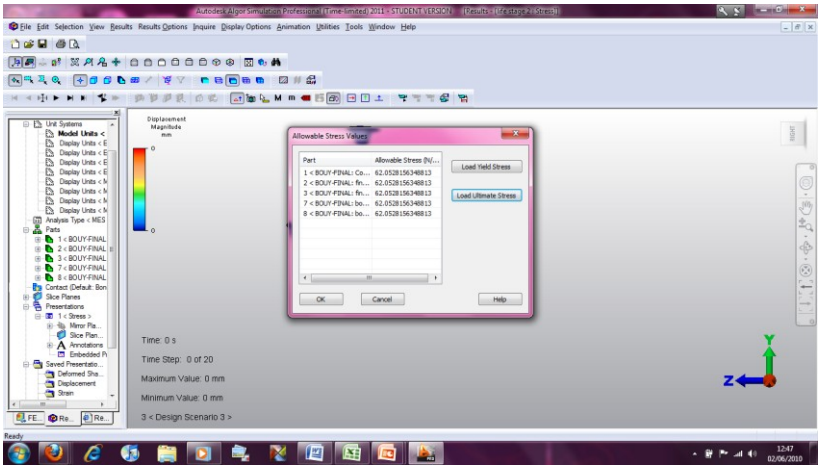
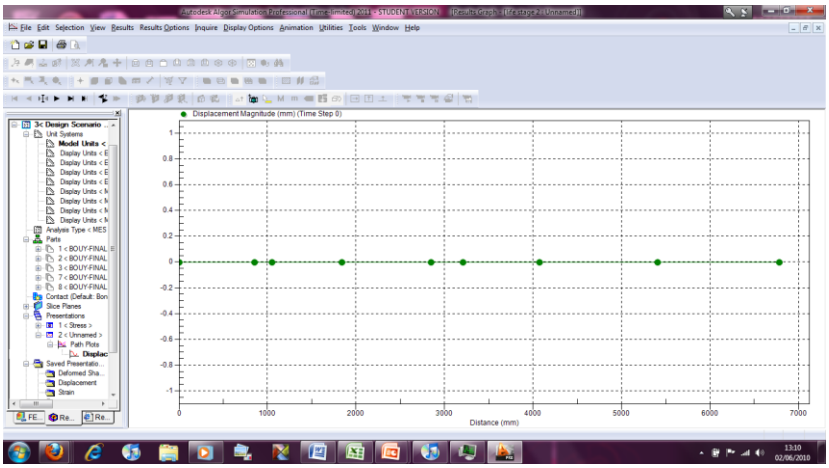


Fig. 34 Von mises stress analysis



Maximum stress levels can also be acertained from the software.

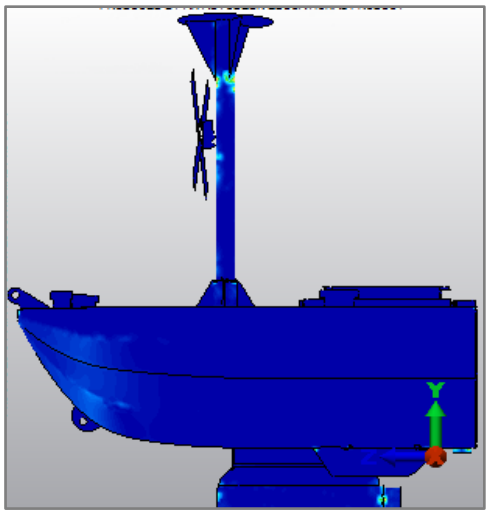
Fig. 35 Maximum stress levels



In addition graphs are produced using given values.

Fig. 35 Graph showing von mises stress analysis

3.5.8.2 Results



This image produced by Autodesk Algor software allows the weak points of the buoy to easily be identified. These are shown in the lighter coloured areas for example towards the top of the mast, front part of the buoys base & on the bottom extremity.

Fig. 36 Buoy weak points

Table 12 Maximum stress level

Part	Allowable Stress (N/..
1 < BOUY-FINAL: Co...	62.0528156348813
2 < BOUY-FINAL: fin...	62.0528156348813
3 < BOUY-FINAL: fin...	62.0528156348813
7 < BOUY-FINAL: bo...	62.0528156348813
8 < BOUY-FINAL: bo...	62.0528156348813

This table shows the maximum stress levels that can be exerted on the AAB before it reaches breaking point. This data is taken from MES RIKS analysis & gives a value of 62.05N

3.6 3D simulations

At the request of the marketing section a 3D animation was created using 3D studio max software in order to provide a pictorial simulation of the Buoys behaviour. This avi File can be used in future presentations made by the LAB.

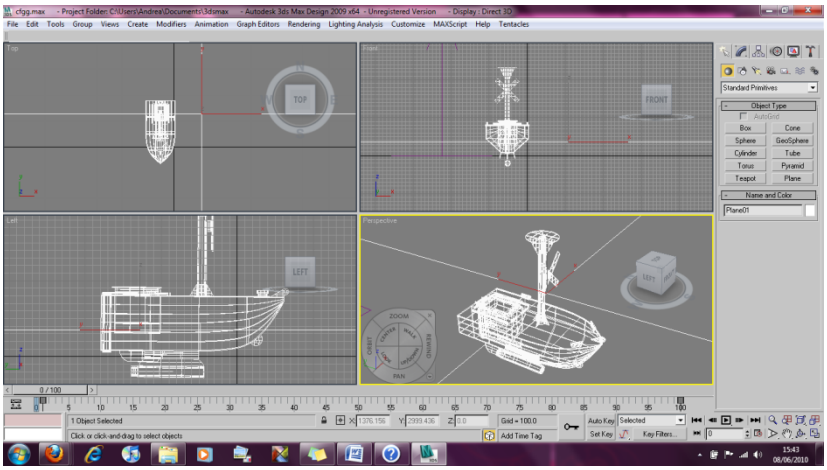


Fig. 37 Max animation1

The first step in the simulation was to import the buoy from solid works. Next a plane was created and positioned in order to simulate the water around the AAB.

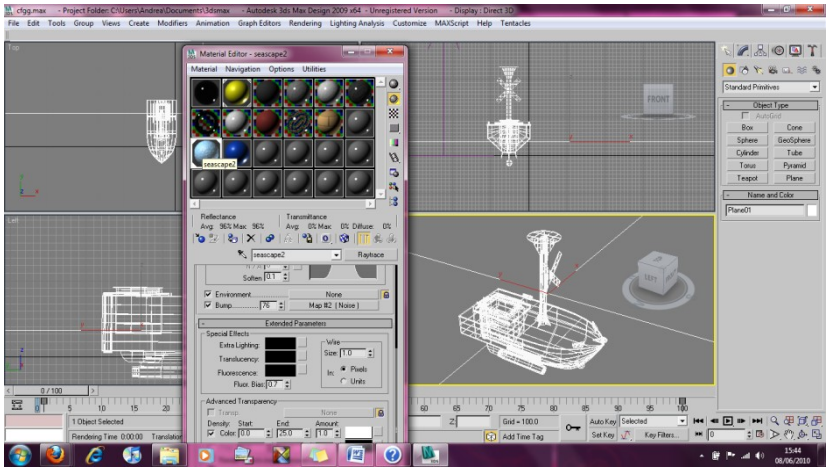
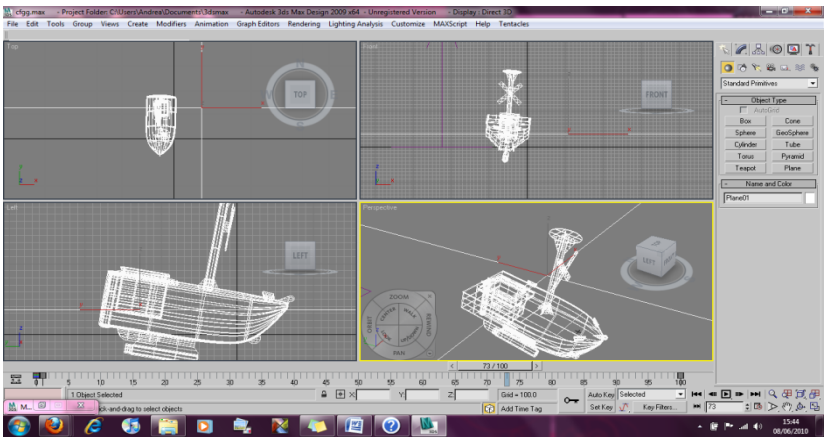


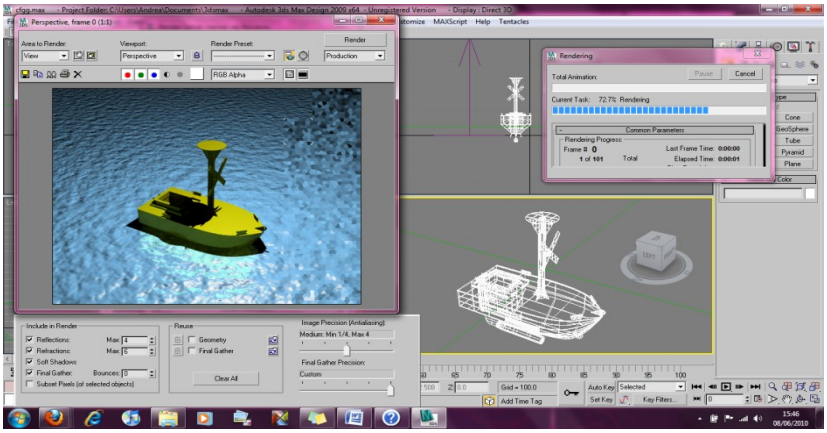
Fig. 38 Max animation 2

Next the materials were assigned using the materials tool. These were chosen appropriately in order to make the simulation appear more realistic.



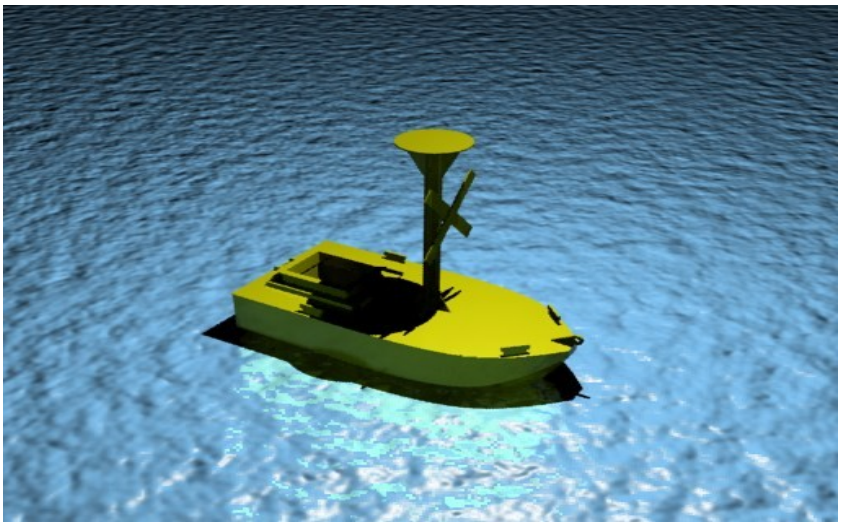
The next step was to create the movement of the buoy within the scene. This was done using the key frame tool & physically moving the orientation of the buoy.

Fig. 39 Max animation 3



Finally lights were added and the scene was rendered. An Avi file was the chosen output as this can be played on most devices/operating systems.

Fig. 40 Max animation 4



To the right the first shot of the animation can be seen. This task has been successful.

Fig. 41 Final animation

3.7 Evaluation

In the beginning the CAD simulation task did not progress as quickly as hoped. At the midterm stage the task was two weeks behind schedule. No simulations had been carried out due to difficulties faced in sourcing appropriate CAD software. However since this point satisfactory progress has been made, the buoy has been structurally

tested using Algor simulation software & theoretical calculations have also helped to make further assessments about the buoy. In addition an animation has been created using 3D studio Max to be used for marketing purposes.

3.7.1 Further Work

Possible future work includes doing a more detailed theoretical CAD simulation. This would be made possible by using more powerful and expensive software such as Catia which has greater analysis capabilities. However as the AAB has already been manufactured and is close to completion in other areas such further analysis can possibly be considered futile. This is the judgement call that the LAB will now have to make.

4. Electronic Design

4.1 Introduction

Due to the needs to monitor operating parameters of electronic equipment and buoy behaviour in the marine environment, Electronic Department of AAB project (EPS 2010) built up a watchdog, which takes care of the good physical and software conditions of the Hercules board and represents the core of the Autonomous Acoustic Buoy, power supply module and the watchdog itself. For those systems that can't be constantly watched by a human, watchdog is the right choice and the best solution. The watchdog is circuit board, which consist of two main parts, hardware and software. These components will trigger a system reset or other corrective action, depending on user settings and immediate needs resulted from operating conditions and environment. For instance: temperature and humidity discrepancies, a hang of main computer, or neglects to regularly service the watchdog. The intention is to bring the system back from the nonresponsive state into normal operation one, or to inform the shore about the current state of the system and buoy in case of non-repairable and irreversible state. As is shown in *Fig.42* the watchdog is going to be placed inside the „Autonomous Acoustic Buoy", which will be offshore for monitoring and registering the marine mammals whistles.

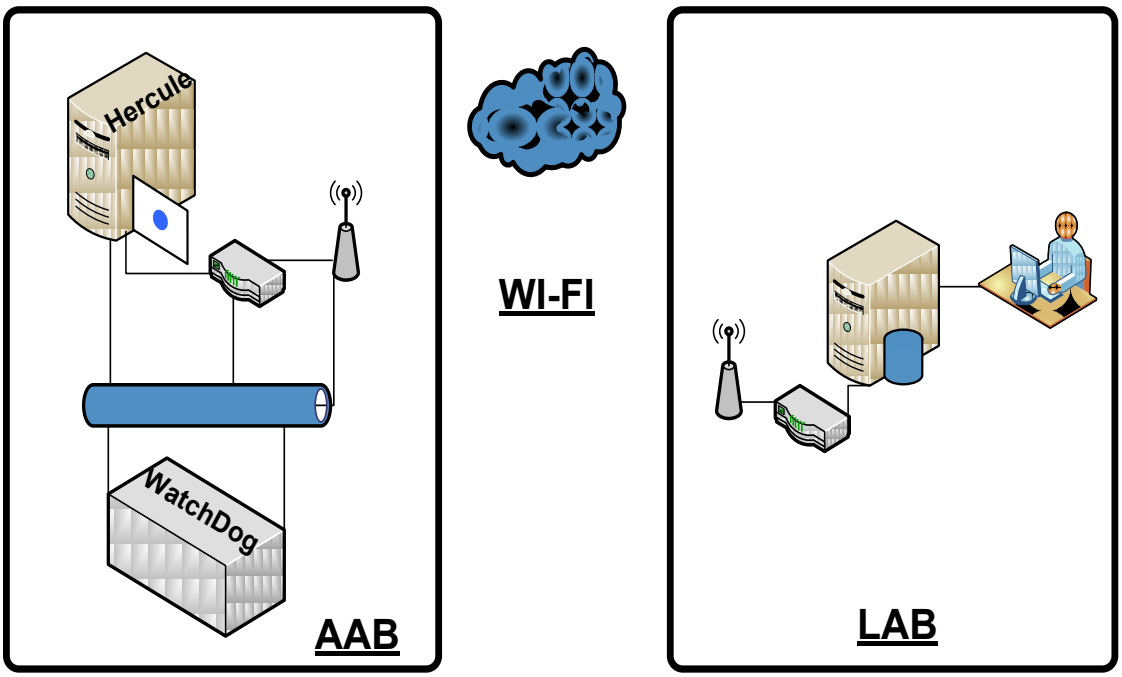


Fig. 42 Overview and Watchdog positioning in the system

The watchdog is a complex device, attempting to save debug information onto a persistent medium. The recorded information is going to be used for debugging the problem that caused the fault. The most common use of a watchdog is in embedded systems, where this specialized timer is often a built-in unit of a microcontroller. In our

case the device has to be more sophisticated, with many features and will use the microcontroller itself as a core of the device.

4.2 Watchdog Functions

Watchdog timers will trigger fail-safe control systems to move into a safety state, such as turning off the main computer, low-voltage detection, and other potentially dangerous subsystems until the fault is cleared.

- **Limiting and saving** the power consumption. Set time limits and constant values in the program, which are going to be used as a guideline conditions for stop the entire system or shut down different its components in order of importance.
- **Protect** the electronic equipment when high temperature or high humidity occurs, also in case of water infiltration due to buoy reversal.
- **Monitor** and register information as temperature, humidity and position of the buoy, which are going to be sent to the shore, where the user can compute them in terms to obtain charts, diagrams and table reports with received data.
- **Emergency message:** In case of irreversible damage, the buoy will inform the shore sending a radio message as a help request.

Using the watchdog will make the Autonomous Acoustic Buoy a self-reliant system. This will save users from direct intervention as well as time and money. In relation to the text written above, the watchdog has specific features which can aid in solving any problems which it may encounter.

4.3 Connection between watchdog function, its hardware and its software

4.3.1 Physical conditions

One of the main functions of the monitoring device is to supervise the temperature, humidity and impacts of the sea against the buoy. The watchdog should take decisions accordingly in terms of resetting or powering down the *Hercules* board. The watchdog has an integrated three axes accelerometer with which to monitor the behaviour of the buoy offshore.

The operating conditions of the *Hercules* board in terms of temperature and humidity are monitored using the *SHT73* sensor from the *Sensirion* Company. This sensor is half-duplex, synchronous, and has his own protocol that needs two *I/O (input/output)* pins of the *PIC* microcontroller. The acquired data is sent via the *USART (Universal Synchronous Asynchronous Receiver Transmitter)* port to the *Hercules COM* port, where gathered data is going to be stored. The stored data will be downloaded to the main computer, so that scientists and engineers can ascertain information about the conditions of the buoy. With this information, they can also monitor in real time the variations of the physical conditions. Temperature, humidity and the behaviour of the sea (accelerometer) are the main parameters supervised by the watchdog, in this way decisions can be taken in terms of buoy functionality.

4.3.2 Levels of danger

Due to the fact that the AAB has to interpret different results with different meanings, and then has to take an appropriate decision, different levels of warning were assigned as references for the buoy:

1. The first level will be to reset the Hercules board in the event of a poor communication signal, or if the Hercules hangs up.
2. The second level of warning will be to power down the Hercules board if the operating conditions fall outside of the acceptable range. In the event of this the watchdog must wait until the conditions have returned to a satisfactory state before turning on the Hercules board.
3. The third level of warning is to be used when the buoy becomes damaged. For example in the event it becomes capsized, water penetrates inside or if the battery is nearly depleted It will send a rescue signal using a radio-transmitter.

According to the levels of danger mentioned above, the AAB project team (EPS 2010) has developed a software program which will operate the microcontroller. As a consequence all the decisions of which *Watchdog* will take, are decided based on the software program.

4.3.3 Software conditions

The main program of the Hercules board will send periodically to the watchdog a signal to inform it that communications between the buoy and the main computer are working properly. Therefore, if the main program of the Hercules board hangs up or communications fails, the watchdog will detect the absence of this periodical signal and will restart the Hercules board. For this task is going to be used one of the *PIC's* timer to count a certain period and the external interrupt feature of the *PIC* microcontroller. If in the established period the watchdog does not get the signal from the *Hercules* board, and the timer overruns, the watchdog will pull-down a digital output that is connected to the reset 'button' of the *Hercules* board. In addition the, *Watchdog* is going to monitor the power consumption and the level of the battery, using the analogue to digital converter of the PIC microcontroller. Based on the received data, the watchdog has to decide which part of the buoy has to be shut down and also conserve the maximum amount of power that it can until the rescue team are able to change battery of the buoy.

In the event of irreversible damage to the buoy *(Level 3)* a further watchdog feature has been added, this is the radio transmitter module which has the task of sending a rescue signal to shore. For this feature we will use two antennas. One antenna is positioned on the top of the buoy and another is placed on the bottom. The bottom antenna will be used in the event that the buoy becomes capsized. Both the top and bottom antennas will broadcast signals when the buoy is exposed to any other improper operating conditions.

4.4 Hardware design

4.4.1 Full hardware buoy system overview

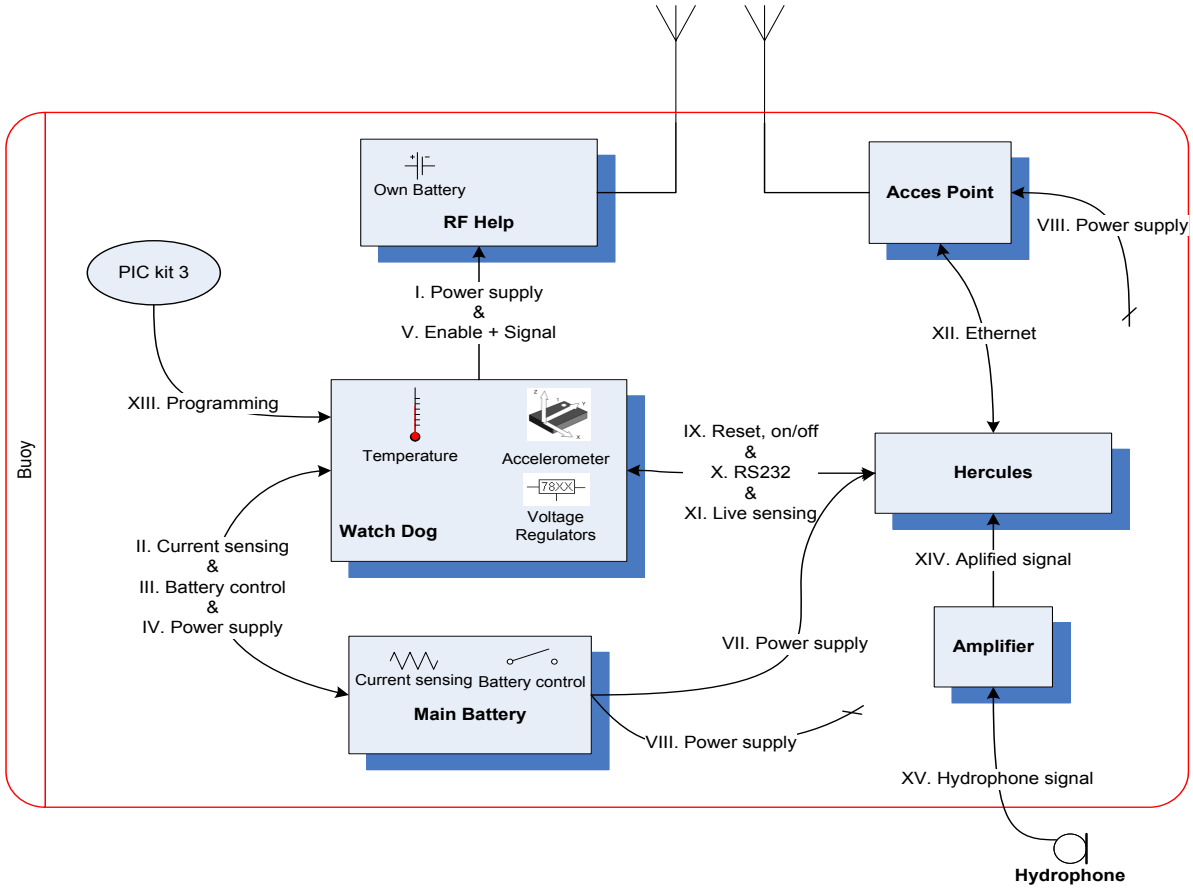


Fig. 43 Full buoy diagram

The full hardware system of the buoy consists of a main battery that supplies power to all of its modules. The Watchdog and RF Help modules also have their own backup battery for use in the event that the main battery becomes dead or becomes so overheated that it needs to be disconnected from the system. If this were to become a reality then without individual backup batteries these two vital modules would not be able to send an essential SOS signal.

The sounds of the sea are recorded by the hydrophone. This hydrophone is connected to an amplifier, and the amplifier in turn to the Hercules board. The Hercules board manages and saves all of the gathered information with the use of an access point. This Hercules board operates the buoys core functionalities, as a result of this it cannot be allowed to hang up. In order to supervise this and ensure that it does not become a reality the watchdog monitors the status of all functionalities within the AAB. This is achieved by the sending of a periodical signal that is generated by the Hercules computer. In the event that the Hercules has become inactive the watchdog will not receive this signal and as a consequence will restart the Hercules board. The Watchdog is also able to send environmental data (for example about temperature and

acceleration) to the Hercules board. In addition the watchdog has the capability of disconnecting the battery from the remainder of the system in the event of water penetration or that the battery becomes overheated. The current that is being consumed by the Hercules board is also supervised by the watchdog in order to detect short-circuits or other anomalies *[Appendix 12].*

4.4.2 Watchdog Schematic

The hardware of the watchdog is divided into a few main parts, each part is referred to as a module. These modules perform specific functions such as monitoring the environment, communication, sensing the power supply, supervising the Hercules board, to name a few. The main modules are the following:

a) Communication between watchdog and Hercules main board
b) Digital temperature and humidity sensor
c) Analogical temperature sensors
d) Power
e) Power sensing
f) Accelerometer
g) LAN activity (Live sensing)
h) Programming port
i) Hercules power control
j) Battery charger

4.4.2.1 Communication between watchdog and Hercules main board

The communications module is based in the *RS-232* standard protocol. As the *TTL* technology of the PIC microcontroller does not match with the *RS-232* standard, we use the transceiver signal conditioner *MAX232* from the *MAXIM* company. This device requires some external capacitors to work.

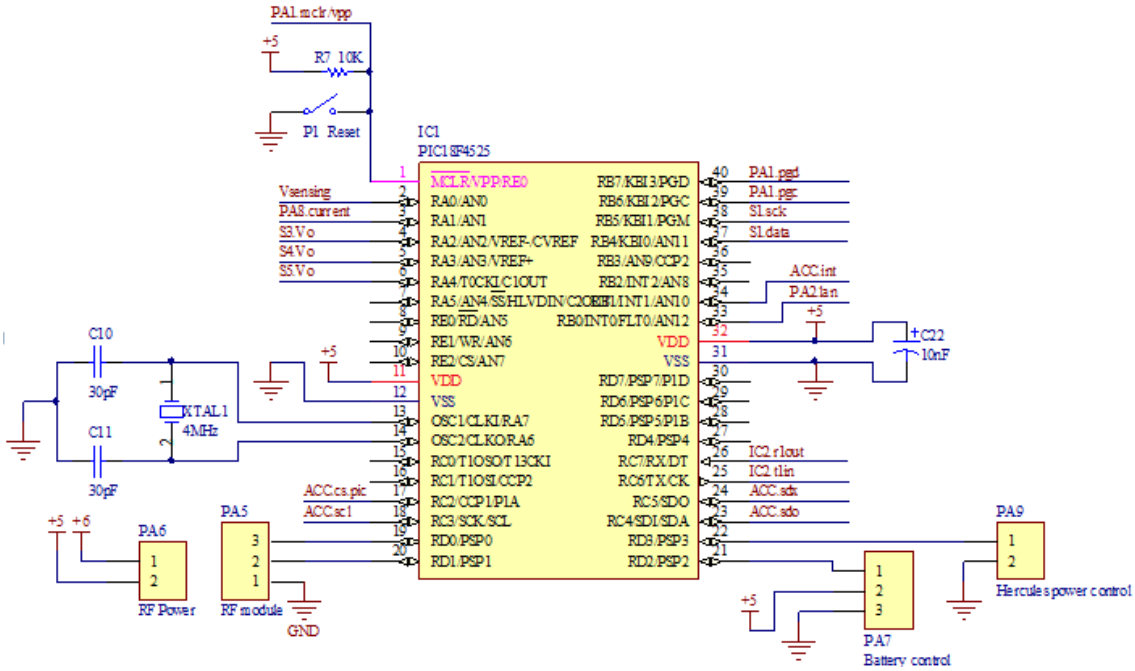


Fig. 44 PIC Microcontroller with the corresponding ports

These external capacitors are C1, C2, C3 and C4. All four are 1µF electrolytic capacitors and this value is the recommended by the MAXIM Company in their specification sheets of such devices.

Fig. 44 shows two ports, these are called *IC2.t1in* and *IC2.r1out* and are virtually connected to pins 25 and 26 of the PIC microcontroller. Virtually connected means that in the schematic they are not linked by a line to avoid what is commonly known as a: 'spaghetti schematic'. We assume that the PIC microcontroller and the MAX-232 integrated circuit are connected by those virtual ports.

In *Fig. 45* we can also see PA3, the prefix PA means Pin Array, and the '3' is just to identify that it is inside the schematic. For the MAX232 encapsulation we've chosen PDIP. This is just to avoid soldering complications and to ensure that too much time is not wasted soldering. The MAX-232 is power supplied by 5V. The capacitor C20 is a decoupling capacitor.

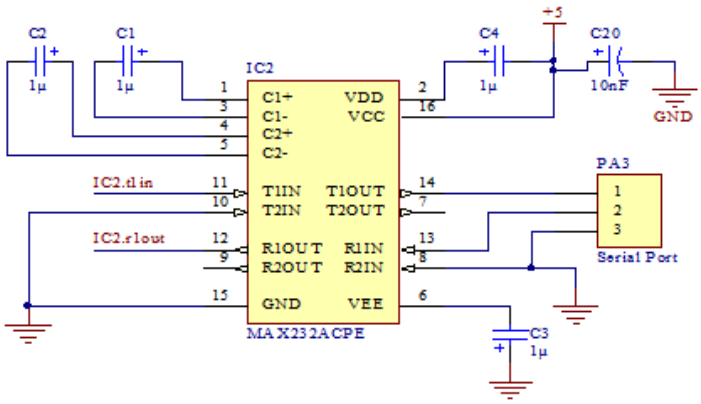


Fig. 45 MAX-232 with the required external components

4.4.2.2 Temperature and humidity sensor

To sense the temperature and humidity an embedded device has been chosen. This contains both features in the same physical device. This device is the SHT73, (it is represented by the part name S1). The S prefix means that it's a sensor, and the '1' is just an identifier inside the schematic. This embedded device is fully calibrated in the factory and therefore it does not require any external electronic equipment to calibrate. It has got a digital synchronous serial output and in addition is fully recommended to work with battery supplied systems as the consumption of the device is only around 28µA.

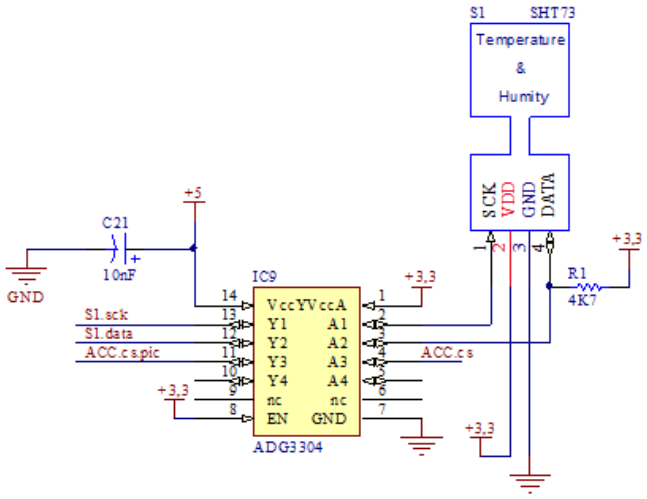


Fig. 46 Humidity and temperature module

This embedded device is sold by the SENSIRION company. The sensor is already soldered onto a small PCB with a pin array meaning that it can be implemented more easily; as a result the integration of this device is quite easy. With regards to the external components that we can see on **Error! Reference source not found.**, the R1 is a 0k ohm pull-up resistor needed for the conditioning of the signal. Additionally the IC9 integrated circuit can be seen, this is a ADG3304 bidirectional logic level adapter. This is because the SHT73 sensor works at +3,3V logic level voltage and also power supply and the PIC microcontroller works at +5V of power and logic level. In order to avoid damaging the device this device is used. Virtual ports linking the IC9 voltage adapter with the PIC Microcontroller can also be viewed in this Image.

4.4.2.3 Analogical temperature sensors

Although the watchdog has one digital sensor of temperature and humidity, it has three more sensors of temperature. This is used to monitor the different parts of the buoy. As humidity does not need to be monitored in all the places where the temperature is sensed, these sensors are not SHT73, they are AD22103.

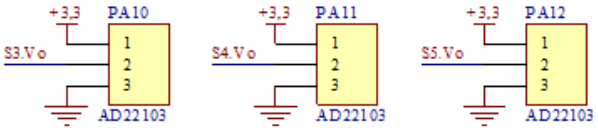


Fig. 47 Analogical and temperature sensors module

The AD22103, is a sensor developed by Analogue Devices. It is analogical in nature and contains the signal conditioning within its own chip. This device is sold in two different encapsulations: TO-92 and SOIC. The board is able to work with either of these encapsulations due to the fact that they are both able to link the sensors with the board ports. These are shown as PA10, PA11 and PA12, see *Fig. 47*.

The sensor has an analogical output proportional to 28mV/ºC and a span of +0ºC to +100ºC. The typical consumption of the device is 0,5mA and therefore is perfect for battery powered devices such the AAB.

4.4.2.4 Power

The circuit is operated using power from the battery of the Hercules main board. As this battery is 12V, and we need 3'3, 5 and 6 to supply the ICs, some current regulation needs to take place. This regulation is done using three positive linear voltage regulators, see *Fig. 48*.

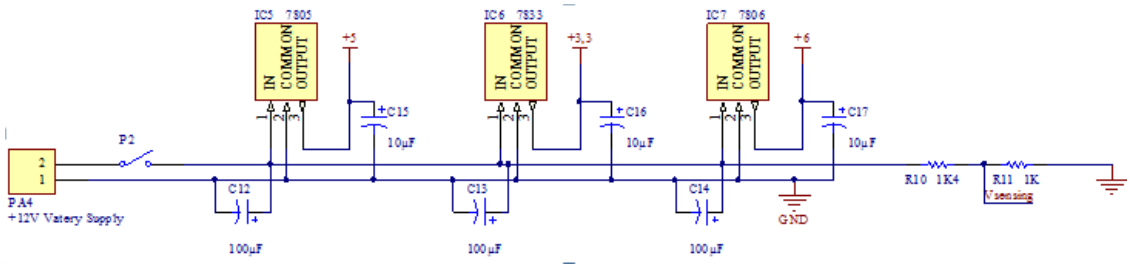


Fig. 48 Power and power sensing modules

To supply the power module, there is the PA4, this is directly connected to the batteries of the Hercules board. In addition the IC5 is used, this ensures that the battery voltage is regulated to 3,3V. The 7805 is used to supply the 5V and the 7806 to supply the 6V.

The 7805 and 7806 regulators can drain a maximum of 1A and the 7833 500mA, this is a few hundred more times than that which the watchdog will require. As a result they will not require heat sinking.

4.4.2.5 Power sensing

The function of the power sensing module is to supervise the voltage level of the Hercules battery. The PIC Microcontroller has got a built in A/D converter, but the maximum voltage that it can sense is 5V. In order not to damage the PIC Microcontroller, we have to (see *Table 14*)adapt the 12V of the battery to 5.

Table 13 Corresponding voltages from the battery to the adapted ones

Battery Voltage	Adapted voltage for PIC Microcontroller
12	5
6	2,5
0	0

This table shows the ecuation (1) demonstration:

$$V_{adapted} = \frac{V_{battery} \cdot 5}{12} \quad (1)$$

To physically implement this literal conversion a voltage divider has been designed. This voltage divider can be seen in the Watchdog schematic**Error! Reference source not ound.**. Voltage is divided by the resistors R10 and R11. In equation (2) we can see the demonstration.

$$\begin{aligned} V_{R11} &= I \cdot R11 \\ 5 &= I \cdot 1K \\ I &= \frac{5}{1k} = 5mA \\ 5mA &= \frac{12}{1k+R10} \\ 1k + R10 &= \frac{12}{5mA} \\ 1k + R10 &= 2400 \\ R10 &= 1400ohm \end{aligned} \quad (2)$$

So, in the R11 the drop voltage will be the adapted one that will be connected to the sensing virtual port which in turn is connected to the PIC Microcontroller analogical channel 0.

4.4.2.6 Accelerometer

The main core of the accelerometer module is the LIS3LV02DL. This is a three axes digital output linear accelerometer that also includes a sensing element and an IC interface. This interface is able to take the information from the sensing element and in addition to provide the measured acceleration signals to the external world through an I2C/SPI serial interface.

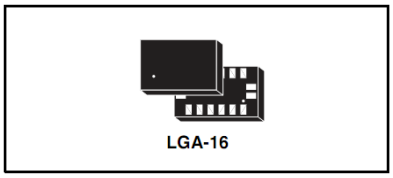


Fig. 49 LIS3LV02DL package

As this device (see *Fig. 49*) is sold in a smd package that is really difficult to solder, the UM0395 adapter board has been selected who to provide an effective solution. This is necessary as the LIS3LV02DL accelerometer is already soldered to a PCB with a pin array output that fits with the DIP standard, see *Fig. 50*.

Fig. 50 Adapted board for the accelerometer

In *Fig. 51* we can see the electronic connections of the accelerometer module. The accelerometer is linked to the microcontroller using the ADG3304 voltage adapter. The operation of this device is explained previously in section b).

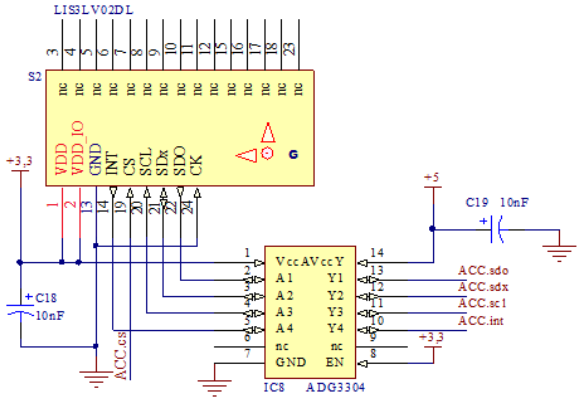


Fig. 51 Accelerometer module

4.4.2.7 LAN activity

This module consists of a simple input port PA2 (see *Fig. 52*) which is directly connected to the PIC microcontroller. The periodical signal that comes from the Hercules board is plugged into this. The periodical signal in question is generated by a program that is used to run the Hercules, therefore, if the Hercules ceases to function correctly the signal will not be produced. After this the watchdog will notice and will consequently execute a reset signal for the Hercules board using the module 'Hercules power control'. The input signal must be +5V voltage level

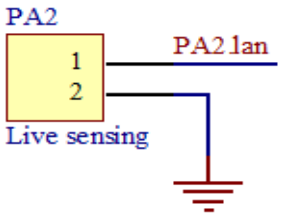


Fig. 52 LAN activity module

4.4.2.8 Programming Port

This module is used to program the memory of the code and configure bits of the PIC microcontroller. The schematic is quite a simple structure. It consists of only three data pins, PA1.mclr/vpp, PA1.pgd and PA1.pgc (see Fig.53) which are linked to the PIC microcontroller.

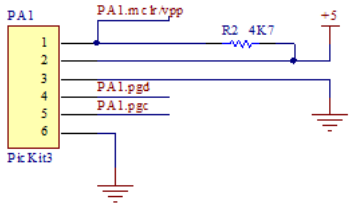


Fig. 53 Programming port module

4.4.2.9 Hercules power control

As we can see the PA9 is the port which manages the power state of the Hercules board. This port is simply connected to the power pin of this board in such a way that it emulates the function of a person touching the power button. If this pin is put up for four seconds, for example, the Hercules board will turn down. This is done in order to avoid the buoy operating in bad weather conditions and will thus help to prevent some types of internal damage.

4.4.2.10 Battery charger

The battery charger module is simply a voltage source from which the current is limited by a resistor. In addition it also contains a diode to avoid reverse voltage connections (see *Fig. 5*).

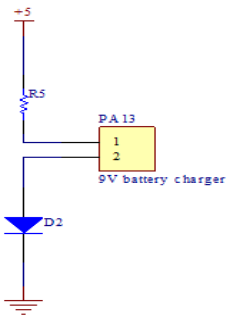


Fig. 54 Battery charger

4.4.3 Expansion Ports

The Watchdog board has been developed to carry out some extra functions such as:

a. Radio transmitter and amplifier

b. Current sensing
c. Battery control

These functionalities are not built into the Watchdog board however it does have the necessary ports enable them to be carried out.

4.4.3.1 Radio transmitter and amplifier

The radio transmitter is needed to send an SOS signal in the case of emergencies. This signal will be emitted by the FM-RTFQ1 module which is sold by RD Solutions Company. This is a fully designed and embedded radio emitter that does not require external components and works in the 868MHz frequency range. We can see the radio transmitter in the *Fig. 55* with the identification IC3.

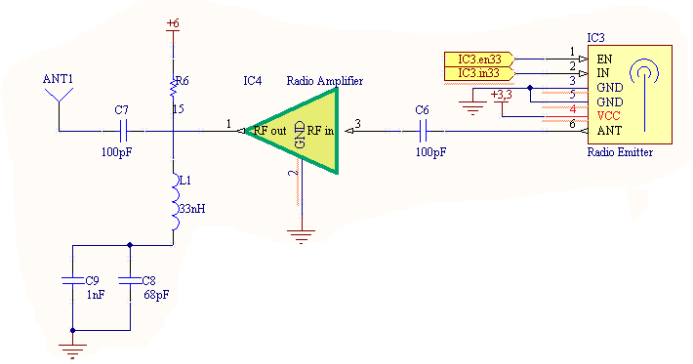


Fig. 55 Radio transmitter with the corresponding radio amplifier

The radio amplifier is required in order to increase the signal from the radio transmitter. In this module, there are many more components than in the previous ones. The radio amplifier consists of the following components*: IC4, C6, R6, C7, ANT1, L1, C8 and C9.* The main core of this module is the IC4. This is a wideband medium power amplifier that will increase the power signal from the radio transmitter. This Silicon Monolithic Microwave Integrated Circuit (*MMIC*) is sold by the Semiconductor division of PHILIPS.

In *Fig.55* we can see the components position and its corresponding values. This position and value is recommended by the specification sheet given by PHILIPS Semiconductor with this device. In the *Watchdog PCB*, the corresponding ports that link the radio transmitter and radio amplifier will be the PA5 and PA6. The PA5 is the power port that will give +5V and +6V to power up the amplifier and the transmitter. PA5 port is the radio control port, this is one of the pins is that will turn on or off the radio device and the other one is used to send the rescue signal to be emitted.

4.4.3.2 Current sensing

The current sensing port, *Fig. 56* , has the task of receiving the proportional voltage in accordance with the current that in real time is being consumed by the main battery.

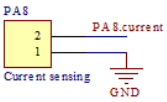


Fig. 56 Current sensing expansion port

The current sensing module should consist of a low resistance resistor in series with the full system and the battery, in this way:

$$I = V \cdot R$$
$$I_{consumed} = V_{resistor} \cdot R_{resistor} \quad (3)$$

4.4.3.3 Battery Control

The battery control expansion port is the PA7, this. It consists of three pins. One is +5V to give the power supply to the module. Another one is the control pin, which is connected to the PIC microcontroller and is which will give the signal to disconnect the full system from the battery in the event that a problem is detected. The third pin is ground.

4.5 System integration

To isolate the watchdog module from the other parts of the *AAB*, the decision was taken to place the *Watchdog* in a separate sealed box. This was important as a result of the operating conditions in which the buoy is to operate, for example water infiltration or extreme shaking. The box must be completely impenetrable in same way that a black box of an airplane is. As a result, if the *Hercules* is in danger, then the Watchdog will not be. The only link between the *Hercules* board and the watchdog is the *SHT73* sensor. This will be placed in the *Hercules* box and linked to the watchdog via the use of cables. The sealed box of the watchdog is going to be powered up with *+12 V* from the battery box using and external connector and cables. Because the batteries also control the electronic circuit which have a certain range for operating conditions it was decided to place another temperature and humidity sensor inside the battery box.

As a backup solution it will be taken into consideration to build the watchdogs own power system supply. In the event that the buoy power system is damaged we can switch the alignment of the watchdog from the general power supply box to the backup power system. This is a small 9V battery that is capable of providing enough power for the board to send rescue signals to the shore. For future improvements of the AAB it is suggested that solar panels are used to power the main supply system. In this way, using a proper electrical system which can convert solar energy to electricity, it will be possible to use energy stored during the day time to recharge the batteries of the buoy. Solar panels will be positioned on top of the buoy and the electrical convertors will be placed in a separate box inside it.

4.6 Communication between Watchdog and Hercules main board

Communication between the watchdog and Hercules main board (see *Fig. 57*), will be made using well insulated wires. Effectively the Hercules II is an embedded CPU board in an EBX form factor that integrates the following subsystems onto a single compact board:

- CPU
- Core PC Chipset
- Video
- Sound
- Ethernet
- Analogue and digital I/O [21]

As a result of the features contained within it, the Hercules II board is the core of the AAB. It represents a computer with many inputs and outputs, both digital and analogical, that allow the Buoy to register marine noise and whistles. This final feature of the Hercules board is the most important in the research process carried out by LAB. As a result the designed watchdog has to communicate with the board in terms of monitoring the operating condition of the main computer. In limiting the buoys exposure to detrimental environmental conditions the quality of acquired sound recordings can be improved.

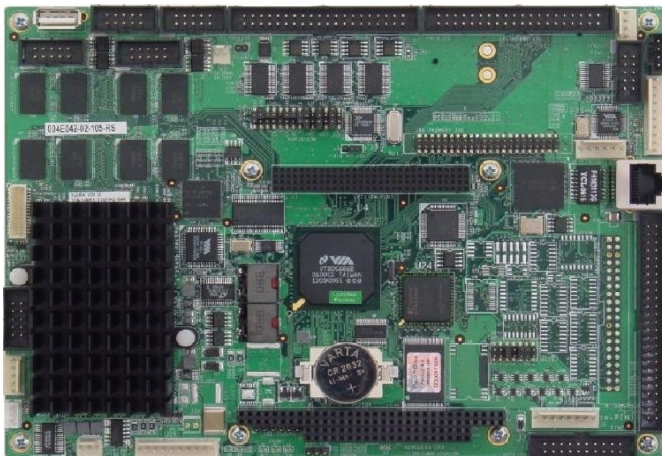


Fig. 57 Hercules II EBX

In order to carry out the aforementioned task the watchdog has various peripheral devices such as different types of sensors. However, the most important function of the watchdog is to detect a “live signal” from the Hercules Board. This signal is sent from the main computer to the watchdog periodically and will trigger a software function from the watchdog. If, the periodical signal is missing for more time than the period established the user, the watchdog will detect the situation and will take an appropriate decision in terms of whether to reset or power off the computer.

4.7 Software Design

The software design for the Watchdog, and namely for *PIC18f4525* microcontroller will

be based, as most embedded systems are, on an infinite loop. As is shown [*Appendix 11]*, the program has three different courses. A main course of the program and two interrupt routines. The interrupts are used for monitoring the external high priority events, such as the hung up of the Hercules board or an external interrupt given by the accelerometer. These types of routines will serve to avoid or treat the event which caused the damage.
The main loop will run forever, and has some critical steps of which it has to follow:

1. Initializing microcontroller peripherals:
    - Input and Output ports of the microcontroller;
    - *Universal Synchronous Asynchronous Receiver Transmitter* port;
    - *Analog to Digital Converter;*
    - Activating the interrupts;
    - Internal timers;
2. Initializing the communication with external peripherals:
    - Accelerometer;
    - Temperature and *Humidity Sensor*;
    - Radio module;
    - *Hercules* board;
3. Data acquisition;
4. Data computation;
5. Sending the computed data through *EUSART* to *Hercules* board;
6. Comparing data with reference values;
7. Depending on results of comparison operation the *Watchdog* has to take the following decisions:
    - Reset the *Hercules* board;
    - Shut down temporary the *Hercules* Board;
    - Shut down permanently the *Hercules* Board;
    - Send rescue signals to the shore;

In next the figure the time evolution of the software is shown. A time of 6 seconds was obtained for an entire cycle. Each cycle is divided into three sections (see *Fig. 58*):

1. Initialization: at this point microcontroller is initializing its peripheral devices;
2. Data acquisition and computation: in this section core of the *Watchdog* receives data related to temperature, humidity, acceleration, power consumption and current sensing. Afterwards data are computed and sent to main computer through USART port.
3. Decisions: at this point computed data are compared with references and if it is necessary the Watchdog takes decision in terms of reset, power off or power on main board.

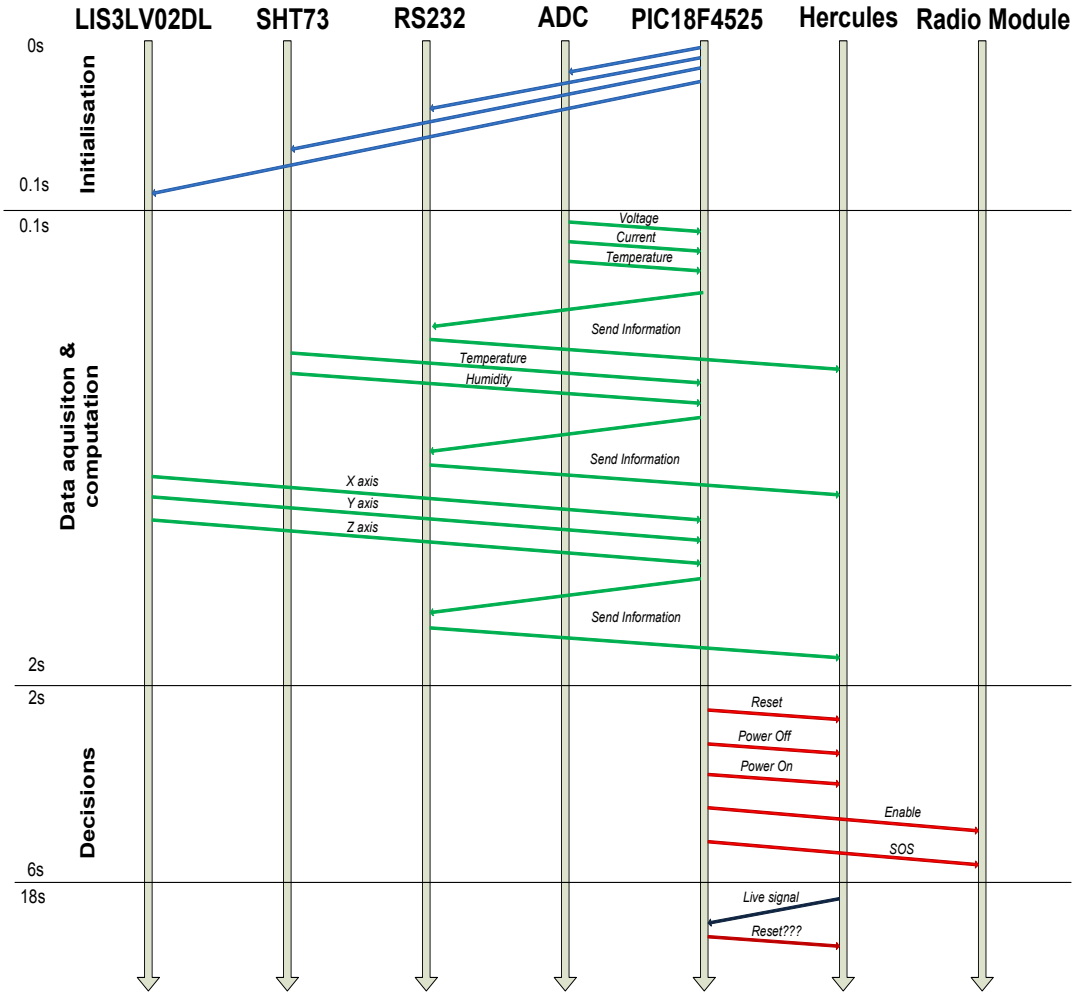


Fig. 58 Time evolution of the software program

Normally every 18 seconds the watchdog has to receive a signal from the Hercules, this is the "live signal", if this does not happen an interrupt occurs and resets the main computer.

4.8 Software Structure

The software was developed using *MPLAB* environment and *MCC18 C* compiler provided by the *Microchip Company (see Fig. 59)*. The software structure is constituted of eleven files, eight source files and three header files (see *Fig. 60*). Each source file contains functions related to identifying, initializing, and controlling the microcontroller's peripheral devices. For instance *SOS.EPS.c* file contains a routine which generates an SOS signal in Morse alphabet. This message is taken by the radio module, which broadcasts it. Links between source files are made with header files calling them. In this way every source file knows about the existence of other source files.

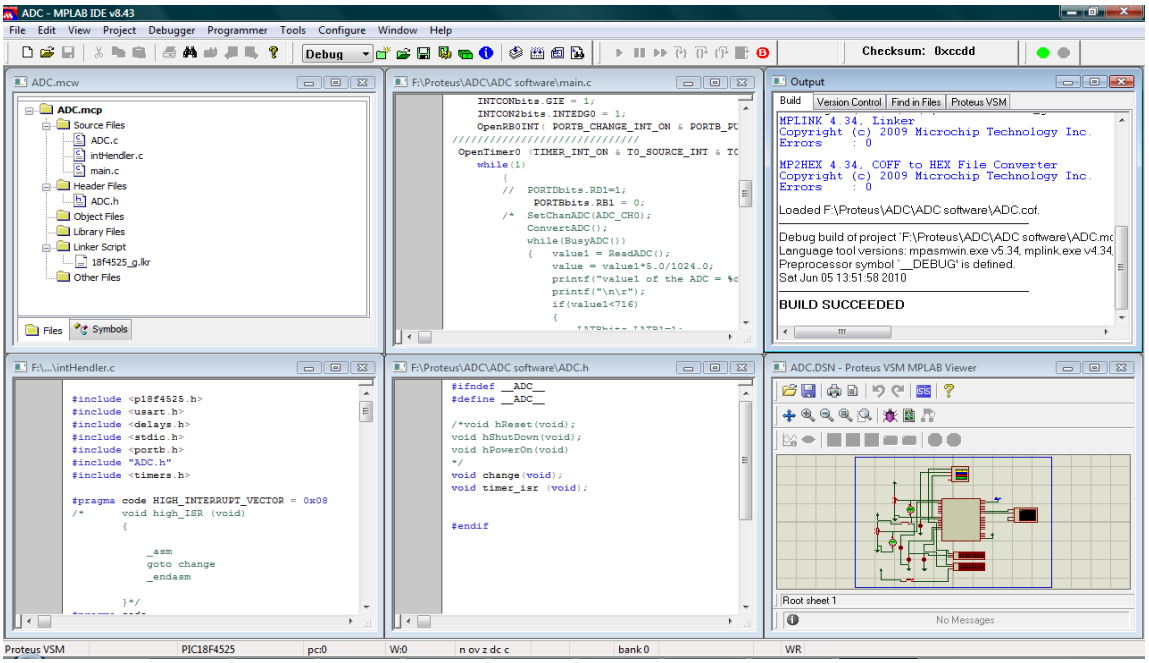


Fig. 59 Development software environment

Inside header files, users can set up global variables used in the program (e.g. *Variable.h*). Furthermore users can configure the microcontroller's ports (e.g. *PortConfiguration.h*). For instance, a microcontroller's pins can be set up as inputs or outputs modifying *TRIS* registers related to the each port. In addition users can modify value on the pins changing PORT or LAT registers value.

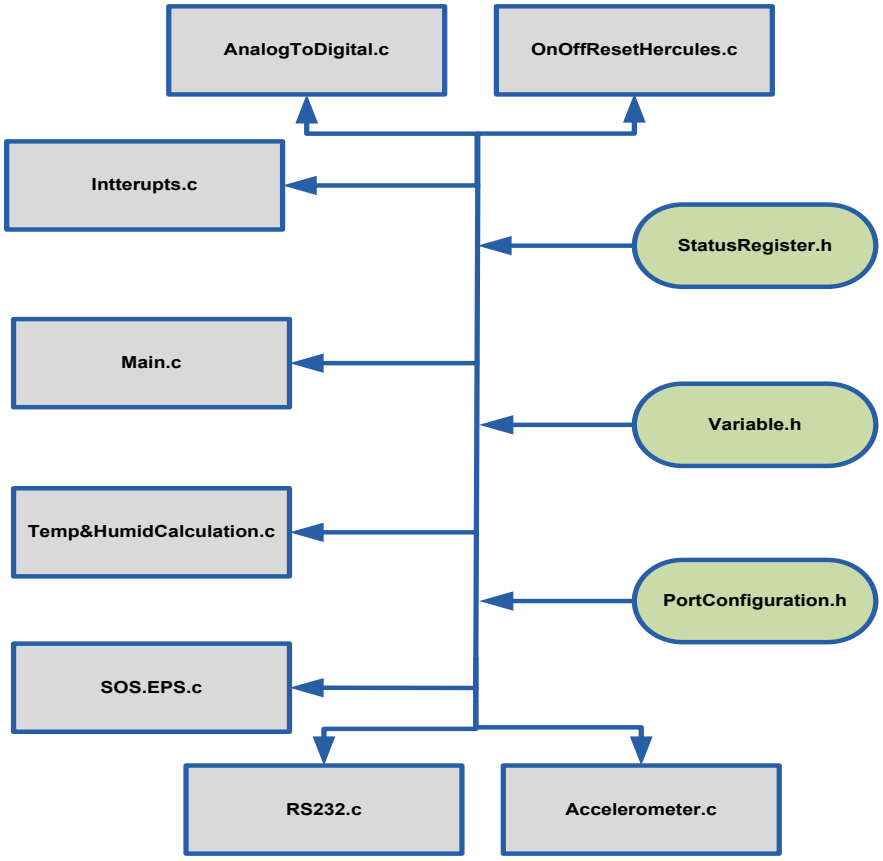


Fig. 60 Software structure

Because the microcontroller *PIC18F4525* has to control different types of peripheral devices such as sensors, which have their own memory and their own registers, it was decided to create another header file (e.g. StatusRegister.h). This file contains information related to the desired information at the time in the internal registers of peripheral devices.

4.9 "Live signal"

The *PIC18F4525* device has multiple interrupt sources and an interrupt priority features that allow most interrupt sources to be assigned a high priority level or a low-priority level. The high-priority interrupt vector is at 0008h and the low priority interrupt vector is at 0018h. High-priority interrupt events will interrupt any low-priority interrupts that may be in progress.[datasheet] For this purpose only high priority interrupts are used, namely external interrupt and timer 0 on an overflow interrupt. These two interrupts are controlled by two *SFR* registers *INTCON* and *INTCON2* [*Appendixe 5*].
Firstly we dedicated two pins of the microcontroller (RD3 and RB3) through which reset signals were to be sent in addition to power off/on signals. These pins are linked to the J7 utility connector from Hercules Board [Hercules]. J7 connector has a reset pin and a power on/off pin. Secondly we developed a software routine to be located in file *OnOffResetHercules.c* which carries out the following steps:

- set up external interrupt as a high priority interrupt;
- set up Timer0 interrupt on overflow as a high priority interrupt;
- in case of external interrupt the routine resets timer;
- in case of Timer0 interrupt the routine pulls down voltage on *RB3* pin for 200ms, which means a reset signal for the Hercules Board;

The periodical signal – "live signal" – is provided from main computer every 18 seconds. If the external interrupt pin *RB0*, doesn't detect any modification of voltage level during 18 seconds, internal timer0 of the microcontroller overflows and triggers its interrupt. [*Appendix 12*]

4.10 SHT73 temperature and humidity sensor

The SHT73 sensor was chosen because of its features:

- Relative humidity and temperature sensors;
- Dew point;
- Fully calibrated, digital output;
- Excellent long-term stability;
- No external components required;
- Ultra low power consumption;
- Surface mountable or 4-pin fully interchangeable;
- Small size;
- Automatic power down; *[25]*

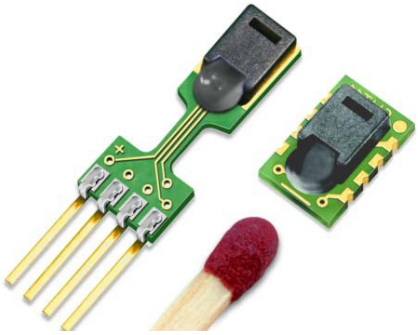


Fig. 61 Humidity and temperature Sensor SHT73

A photo of SHT73 sensor is shown in *Fig.61*. Depending on needs and designer opinion the choice was made between the *SMD* chip and a through-hole device. After much consideration the trough-hole device was chosen. The main advantage of this sensor is that in a single chip there are two traducers which can use the same resources that are provided by the microcontroller. In this case the design of watchdog is going to be more versatile and open for further development.

4.11 Communication between microcontroller and SHT73

For establishing communication between sensor and microcontroller two pins from PORTB of microcontroller are dedicated, namely RB4 and RB5, these represent DATA line and SCK line.

4.11.1 Start up Sensor

To make SHT73 sensor work VDD = 3.3V power supply voltage was chosen. The slow rate during power up should not fall below 1V/ms. After power-up the sensor needs 11ms to arrive in Sleep State, therefore before that time it is prohibited to send any other command. [*25*]

4.11.2 Sending a Command to initiate a transmission

A Transmission Start sequence has to be issued in order to begin the communication between devices. It consists of a lowering of the DATA line while SCK is high, followed by a low pulse on SCK and raising DATA again while SCK is still high [*25*]. The subsequent command consists of three address bits and five command bits. The SHT73 indicates the proper reception of a command by pulling the DATA pin low (ACK bit) after the falling edge of the 8th SCK clock. The DATA line is released (and goes high) after the falling edge of the 9th SCK clock. (see Hardware simulation chapter)

4.11.3 Measurement of RH and T

After issuing a measurement command (‘00000101’ for relative humidity, ‘00000011’ for temperature) the controller has to wait for the measurement to complete. This takes a maximum of 320 ms for a 14bit measurement. The time varies with the speed of the internal oscillator and can be lower by up to 30%. To signal the completion of a measurement, the SHT73 pulls data line low and enters Idle Mode. The controller must wait for this Data Ready signal before restarting SCK to readout the data. Measurement data is stored until readout, therefore the controller can continue with other tasks and readout at its convenience. Two bytes of measurement data and one byte of CRC checksum (optional) will then be transmitted. The microcontroller must acknowledge each byte by pulling the DATA line low. All values are MSB first, right justified (e.g. the 5th SCK is MSB for a 12bit value, for a 8bit result the first byte is not used). Communication terminates after the acknowledge bit of the CRC data. The device automatically returns to Sleep Mode after measurement and communication are completed. *[Appendix 9]*
The temperature sensor is very linear by design. The following formula is used to convert digital readout (SOT) to temperature value, with coefficients given in *[Appendix 10]:*

$$T = d_1 + d_2 \times SO_T \quad (4)$$

4.11.4 Humidity compensation

For compensating non-linearity of the humidity sensor and for obtaining the full accuracy of the sensor it is recommended to convert the humidity readout (SORH) with the following formula with coefficients given in *Table 35.[Appendix 10]*.

$$RH_{liniar} = c_1 + c_2 \times SO_{RH} + c_3 \times SO_{RH}^2 \ (\%RH) \quad (5)$$

4.11.5 Temperature compensation of Humidity Signal

For temperatures significantly different from 25°C (~77°F) the humidity signal requires temperature compensation. The temperature correction corresponds roughly to 0.12%RH/°C at 50%RH. Coefficients for the temperature compensation are given in *Table 37*.

$$RH_{true} = (T_{\circ C} - 25) \times (t_1 + t_2 \times SO_{RH}) + RH_{linear} \quad (6)$$

4.11.6 Dew point computation

SHT73 is not measuring dew point directly. However dew point can be derived from humidity and temperature readings. Since humidity and temperature are both measured on the same monolithic chip, the *SHT73* allows superb dew point measurements. For dew point (Td) calculations there are various formulas to be applied, most of them quite complicated. For the temperature range of -40 – 50°C the following approximation provides good accuracy with parameters given in table below:

$$T_d(RH,T) = T_n \times \frac{ln\left(\frac{RH}{100\%}\right) + \frac{m \times T}{T_n + T}}{m - ln\left(\frac{RH}{100\%}\right) - \frac{m \times T}{T_n + T}} \quad (7)$$

Table 14 Parameters for dew point calculation

Temperature Range	Tn(◦C)	m
Above water, 0 - 50◦C	243.12	17.62
Above ice, -40 - 0◦C	272.62	22.46

This task is not implemented yet, however it could be a good starting point for the future development of the AAB.

4.12 Power sensing

Another task that we have to face is that of power consumption monitoring. For this approach it was decided to use an Analogue-to-Digital converter module of the PIC18F4525 microcontroller. In this way we are using 2 out of a possible 13 A/D channels, one for current sensing and one for voltage sensing. In effect we are

monitoring two voltages because the data is easy to process. When voltage and current are known it is simply a matter of using mathematical formula in order to find out power consumption.

$$P = U \times I \quad (8)$$

4.12.1 Analogical to Digital Conversion

There are 13 Analogical-to-Digital (A/D) converter modules within the PIC18F4525 device. This module allows the conversion of an analogical input signal to a corresponding 10-bit digital number. The module is controlled by the following registers:

- A/D Result High Register (*ADRESH*);
- A/D Result Low Register (*ADRESL*);
- A/D Control Register 0 (*ADCON0*);
- A/D Control Register 1 (*ADCON1*);
- A/D Control Register 2 (*ADCON2*);

By programming in the right way these registers user can choose as many analogical inputs as he needs, which are working one at the time using an internal multiplexor [*Appendix 8*]. For software development we faced a small issue in terms of acquisition time. The minimum acquisition time is 2.4 μs and consists of:

TACQ = Amplifier Settling Time + Holding Capacitor Charging Time + Temperature Coefficient

TACQ = TAMP + TC + TCOFF

TACQ = 0.2 μs + 1 μs + 1.2μs = 2.4 μs

A simple applied formula gives us current and voltage:

$$U = \frac{U_{in} \times 5V}{1024} [V] \quad (9)$$

$$I = \frac{I_{in} \times 5000mA}{1024} [mA] \quad (10)$$

Where U_{in} and I_{in} are inputs of voltage and current respectively, and U and I are computed voltage and current, which are used for power consumption computation.

4.13 Behaviour detection of the buoy

For monitoring the buoys behaviour offshore 3 axis digital acceleration sensors *LIS3LV02DL* have been used. Some of its features are listed below:

- 2.16 V to 3.6 V single supply operation
- 1.8 V compatible I/O
- I2C/SPI digital output interfaces
- Programmable 12 or 16 bit data representation
- Interrupt activated by motion
- Programmable interrupt threshold
- Embedded self test
- High shock survivability [32]

4.13.1 SPI communication port

The SPI mode of PIC microcontroller allows 8 bits of data to be synchronously transmitted and received simultaneously. All four SPI modes are supported. To accomplish communication, typically three pins are used:

- Serial Data Out (SDO) – RC5/SDO
- Serial Data In (SDI) – RC4/SDI/SDA
- Serial Clock (SCK) – RC3/SCK/SCL

In addition the sensor requires a chip select channel which was set up using the RC2 pin. [*27*]

4.13.2 SPI bus interface

The *LIS3LV02DL* SPI is a bus slave. The SPI allows us to write, and read the registers of the device. The serial interface interacts with the outside world with the 4 wires: **CS**, **SPC**, **SDI** and **SDO**.

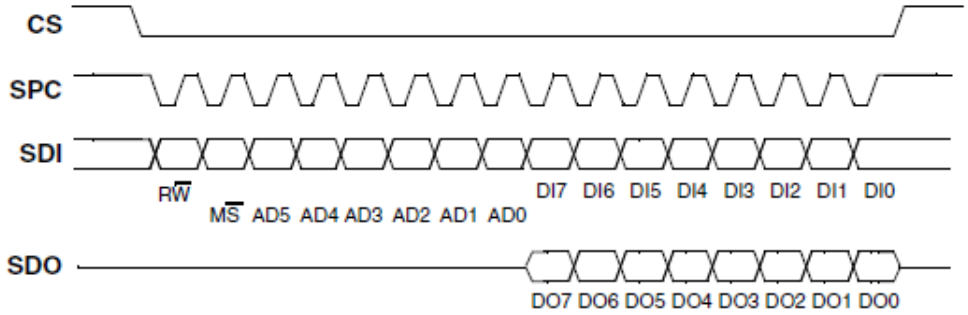


Fig. 62 Read and Write protocol

CS is the Serial Port Enable and it is controlled by the SPI master. It is low at the start of the transmission and goes back high at the end. **SPC** is the Serial Port Clock and it is controlled by the SPI master. It is stopped high when **CS** is high (no transmission). **SDI** and **SDO** are respectively the Serial Port Data Input and Output. Those lines are driven at the falling edge of **SPC** and should be captured at the rising edge of **SPC**. Both the Read Register and Write Register commands are completed in 16 clock pulses or in multiple of 8 in case of multiple byte read/write. Bit duration is the time between two falling edges of **SPC**. The first bit (bit 0) starts at the first falling edge of **SPC** after the falling edge of **CS** while the last bit (bit 15, bit 23, ...) starts at the last falling edge of SPC just before the rising edge of **CS**.

bit 0: RW bit. When 0, the data DI(7:0) is written into the device. When 1, the data DO(7:0) from the device is read. In latter case, the chip will drive **SDO** at the start of bit 8.
bit 1: MS bit. When 0, the address will remain unchanged in multiple read/write commands. When 1, the address will be auto incremented in multiple read/write commands.
bit 2-7: address AD(5:0). This is the address field of the indexed register.
bit 8-15: data DI(7:0) (write mode). This is the data that will be written into the device (MSb first).
bit 8-15: data DO(7:0) (read mode). This is the data that will be read from the device (MSb first).
In multiple read/write commands further blocks of 8 clock periods will be added. When MS bit is 0 the address used to read/write data remains the same for every

block. When MS bit is ‘1’ the address used to read/write data is incremented at every block. The function and the behaviour of **SDI** and **SDO** remain unchanged. [32]
For a proper communication between devices some of the accelerometer registers have to be set up in terms to get the desired results [A*ppendix 11*].

4.14 Serial communication

All data received from microcontroller’s peripheral devices is sent through the serial port of the microcontroller to the *Hercules* main board. The communication protocol is RS232 and is based on a three wire resource. Data sent has a set format which looks like that found in the following table:

Table 15 Data transmition format

T = ± xx,xx C

H = xx,x %

V = xx.x V

I = xx.x I

Xaxis = xg

Yaxis = xg

Zaxis = xg

To enable the serial port, *MSSP* Enable bit, *SSPEN* (*SSPCON1<5>*), must be set. To reset or reconfigure *SPI* mode, clear the *SSPEN* bit, reinitialize the *SSPCON* registers and then set the *SSPEN* bit. This configures the *SDI, SDO, SCK* and *SS* pins as serial port pins. For the pins to behave as the serial port function, some must have their data direction bits (in the TRIS register) appropriately programmed as follows:

• SDI is automatically controlled by the SPI module

• SDO must have TRISC<5> bit cleared

• SCK (Master mode) must have TRISC<3> bit cleared

• SCK (Slave mode) must have TRISC<3> bit set

• SS must have TRISA<5> bit set

To set up an Asynchronous Transmission, it needs to work with the *TXSTA* and *SPBRGH:SPBRG* registers of the *PIC* microcontroller:

- Initialize the *SPBRGH:SPBRG* registers for the appropriate baud rate. Set or clear the *BRGH* and *BRG16* bits, as required, to achieve the desired baud rate.
- Enable the asynchronous serial port by clearing bit *SYNC*, and setting bit *SPEN*.
- If interrupts are desired, set enable bit *TXIE*.

- If 9-bit transmission is desired set transmit bit *TX9*. This can be used as address/data bit.
- Enable the transmission by setting bit, *TXEN*, which will also set bit, *TXIF*.
- If 9-bit transmission is selected, the ninth bit should be loaded in bit, *TX9D*.
- Load data to the *TXREG* register (starts transmission).
- If using interrupts, ensure that the *GIE* and *PEIE* bits in the *INTCON* register *(INTCON<7:6>)* are set.
- Also *TRISC<7>* and *TRISC<6>* bit must be set as digital outputs; *[27]*

USART port of the microcontroller can have the function to both transmit and receive information. To receive information from any peripheral devices, in our case from the Hercules board, the port has to be set up for data reading *[Appendix 7]*. In this way the user which controls main computer can also control the watchdog by writing in its registers information for further actions. This task can be easily accomplished by the next team of EPS students.

4.15 Hardware simulation and obtained results

Before implementing on a real PCB the designed schematic, we tested and simulated it. For the simulation process three different steps were applied:

1. Software simulation of the hardware step using Proteus environment:

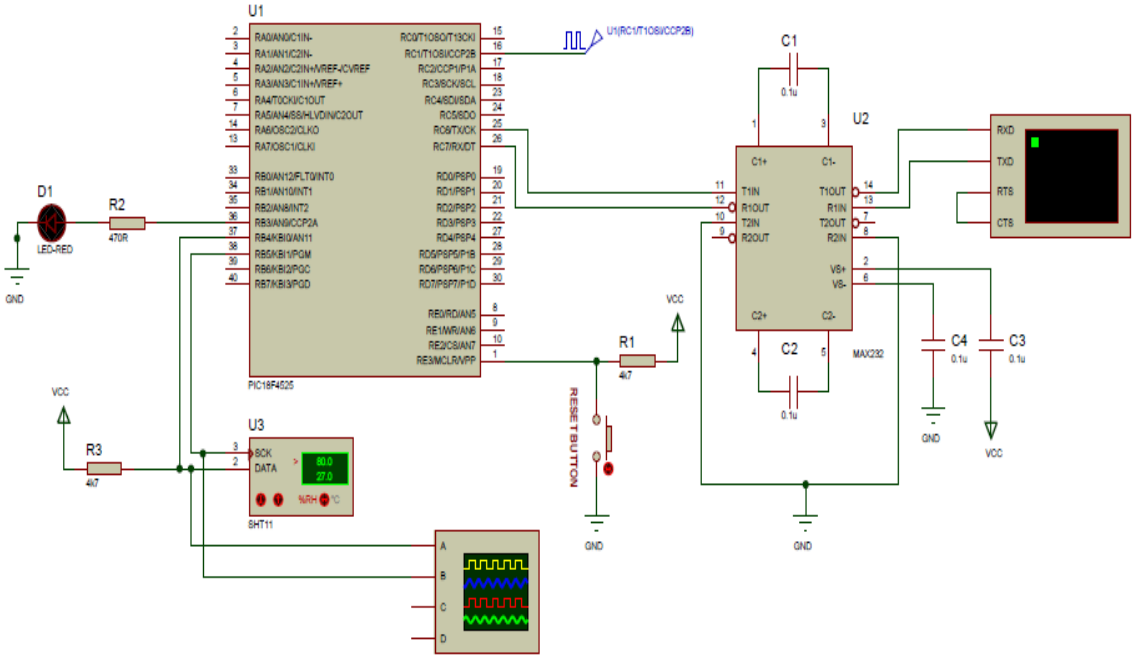


Fig. 63 Watchdog schematic

2. Hardware simulation using prototype boards and electronic devices:

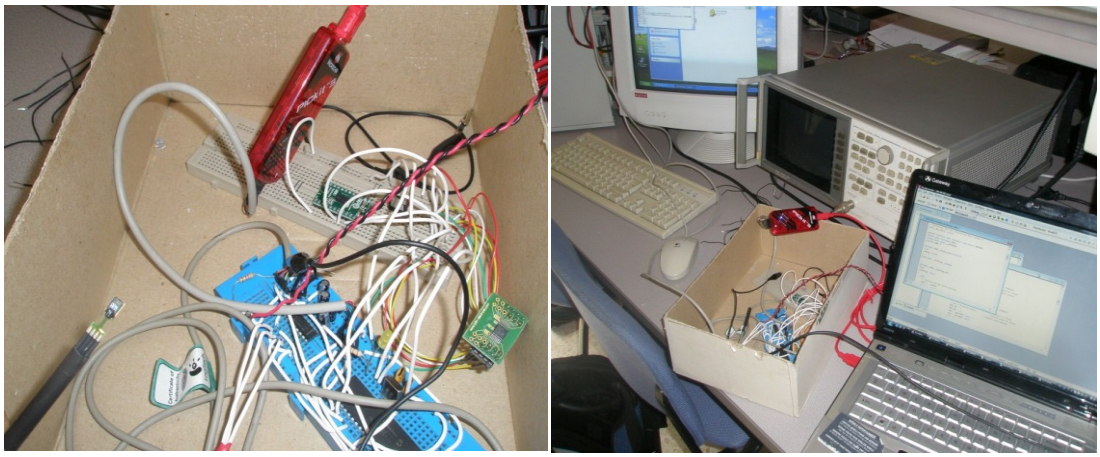


Fig. 64 Hardware simulation step

3. Final product simulation and testing:

Fig. 65 Final product testing

4.15.1 Software simulation of the hardware step using Proteus environment

To simulate the circuit which testing the temperature and humidity sensor, acceleration sensor, external interrupt feature, analogue to digital conversion, and implements serial communication between microcontroller and a computer, it is necessary to have electrical models of the following components, as shown in *Fig.63*:

1) *PIC18F4525* Microcontroller;
2) Adjusting voltage levels circuit to facilitate 2 wires communication, *MAX232*;
3) A virtual terminal which replaces the serial *COM* port of the computer;
4) SHT73 temperature and humidity sensor;
5) Accelerometer *LIS3LV02DL;*
6) *5V* power source*;*

The communication is made using two lines, one is a clock line and the other one is a data line. Both wires are bidirectional, for receiving and transmitting data. The *MAX232* circuit is connected in a classical design using small range capacitors. The microcontroller is the device which will start or stop the data exchange, being programmed in a certain way. Virtual terminal is a tool provided by Proteus environment which is simulating serial computer COM port. The *SHT73* humidity and temperature sensor doesn't require an SPI port as it has its own protocol that needs to be set by the programmer using the software program. For this we will need two I/O

pins of the microcontroller, *RB4* and *RB5*. Operating range in terms of temperature is -40◦C and +123◦C, and in terms of humidity is 0-100% which is the operating range of the microcontroller.
Because of the very low power consumption of the sensor the samples can be taken once a second not often. Also it's not needed to take samples very often of temperature and humidity, so for less power consumption of the entire schematic can be reduced by programming the microcontroller in sleep mode. The decision is going to be taken later on how often samples should be taken corresponding to the other functions that watchdog has to make.

After the software simulation and emulation almost the same result in relation to the datasheet was obtained. In the following figures the results are shown, with mention that the yellow waveform is *DATA* line, and the blue waveform is clock line. Also the left of the figures contain data obtained from simulation and on the right side are waveforms from the datasheet.

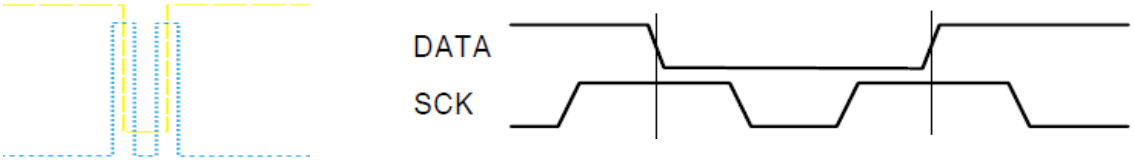


Fig. 66 Start transmision sequence

For easy understanding and implementation of the required sequences of data and clock signals for communication between the microcontroller and sensor, state machines were developed as shown in the next figure. This implements the start of the transmission sequence.

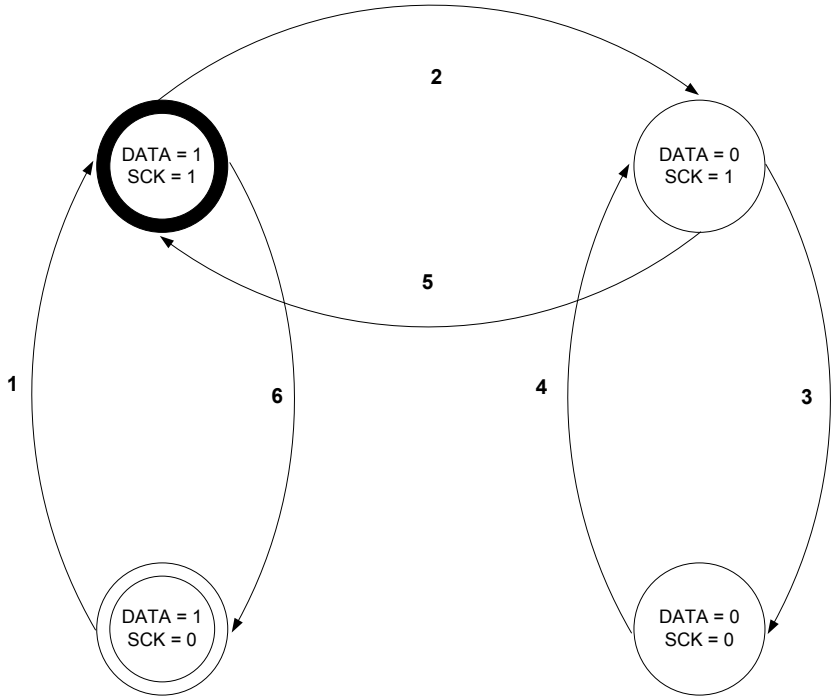


Fig. 67 State machine of start transmission sequence

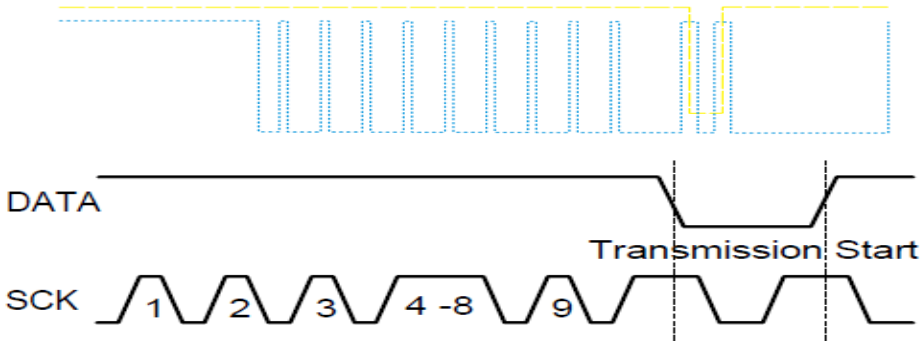


Fig. 68 Reset connection sequence

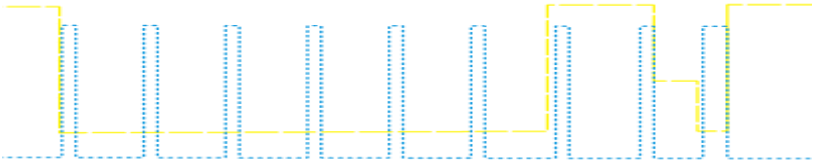


Fig. 69 Command sequence for temperature measurement: 0x03

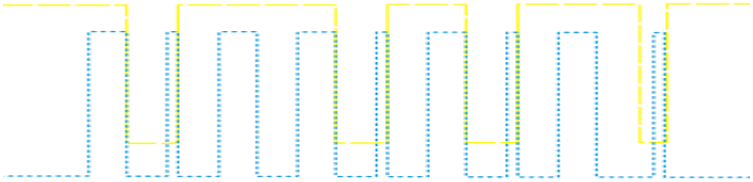


Fig. 70 First received byte of temperature measurement

The following screen shot shows an example of using a virtual terminal for the simulation of the *COM* port of a computer. The port is used for displaying data such as temperature and humidity.

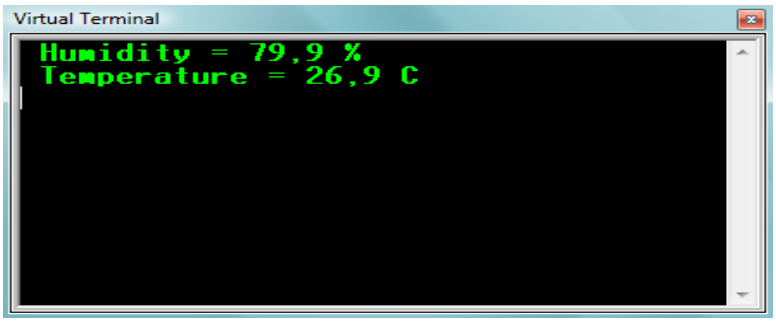


Fig. 71 Sample of temperature and humidity measurement;

4.15.2 Software Errors

It needs to be mentioned that samples are taken with 14 bit resolution for temperature measurement and with 12 bits for humidity measurement. Because of data convertions and mathematical computation also because of the empirical determined coeficients of temperature and humidity compensation, the results are not very precise. The smallest error for temperature is 0.1C and for humidity is 0.5%. These rates are related to the normal range of operation for the WDT. The error goes up to

1,5C for temperature and 5% for humidity for operation conditions in the extreme range.

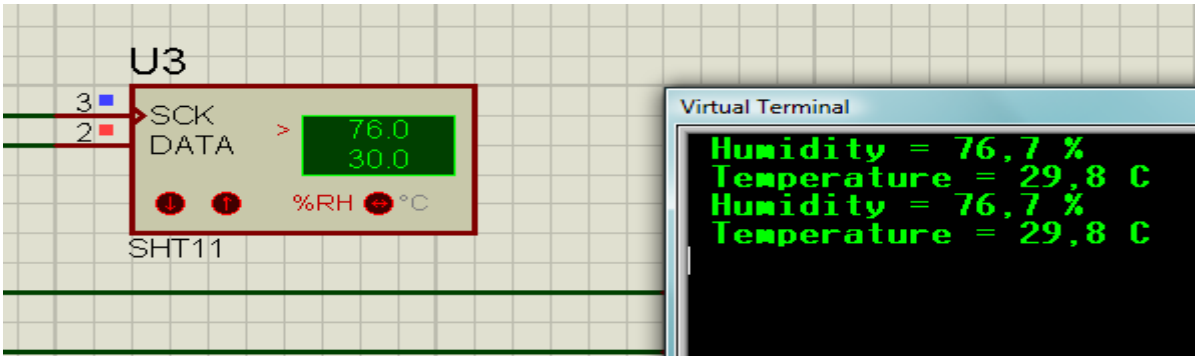


Fig. 72 Error between real data and computed data

A 10 bit resolution conversion of power consumption with 1 LSb error was also obtained. Acceleration obtained using a 14 bit resolution has no error besides factory errors. The reason that makes us to believe that there is no error is the fact that the interface between accelerometer and microcontroller is fully digital.

4.16 Versatility

The watchdog was designed in such a way that it would be versatile. In the persuit of this goal, the printed circuit board has following features:

- Unused pins of the microcontroller were placed aside with a specific type of connectors;
- The pins can be used to connect new devices to the printed circuit;
- As the logical consequence of the preview feature is programmed in a certain way, the microcontroller is able to perform other functions. These functions will trigger an external device using the unused pins;
- To connect the peripheral devices to the printed circuit board specific sockets are used;
- Usually the sockets are universal and are compatible with other devices.

4.17 Conclusions and further goals

Most embedded systems that include high integration peripherals have some sort of built-in Watchdog. This is also the case with the Hercules board in the Autonomous Acoustic Buoy. It has to be avoided apart from in the most cost-sensitive or benign systems. Internal units offer minimal protection from rogue code, and don't offer any protection against external factors as optimal working condition. Runaway software may reprogram the watchdog controller and in addition many internal watchdogs will not generate a proper reset therefore any failure of the processor will make it impossible to put the hardware into a safe state. An efficient watchdog must be independent of the CPU it is trying to protect. For this reason the external watchdog was designed for the Autonomous Acoustic Buoy. The device will monitor the buoys operating conditions ensuring that weather conditions and power supply do not impede or restrict the operations of the Hercules board.

For the further development of the Watchdog it is recommended that the microcontroller's facilities are utilised. The first point is to take advantage of the USART port not only for transmitting information, but also for receiving information. By receiving data, the software program which triggers the microcontroller can save information into its internal data memory, and afterwards use it to write internal registers of the device in order to modify its functionality. Secondly it is strongly suggested that the remainder of the analogue to digital channels of the microcontroller are used by the addition of analogical sensors.

5. Marketing plan

5.1 Goal and Aim of this project

As previously mentioned the 2010 team is the third group to work with the LAB on the AAB project. Our main task is to further develop the design and functionality of the AAB. In addition it is also our task to design a marketing plan with the aim of creating a strategy with which to introduce the AAB onto the market.

Last year the marketing part of the Project was started. Students of the 2009 project group have collected and maintained information about the company and its product, and in addition have also developed a leaflet. Taking this into account it is the aim of the 2010 team to further advance the design of a strategy to enter the market.

5.2 Introduction

Ocean noise has always existed in both natural and biological forms. However in recent years a large increase in artificial sound pollution sources has become a threat to its balance.

Cetaceans can be considered as bio-indicators of the acoustic balance in the oceans. To gain knowledge about their way of perceiving and communicating in the environment, it is important to investigate in the conservation of the marine ecosystems and the development of sustainable human activities.

It is difficult to find financial support, because the effects of noise pollution on the marine environment have not yet been completely implemented in national programs. At the moment the financial support is from private sources to guarantee continuation of this research.

The development of a sustainable marine environment concerns everyone. With some support we can implement solutions from science and applied research in order to bring back the important acoustic balance to the sea [39].

5.2.1 Noise pollution

Before further progress can be made, it is important to know what is meant by ocean noise.
Human activities which produce underwater noise pollution are the following:

- Shipping,
- Offshore oil/gas exploration and production,
- Industrial and military sonar,
- Experimental acoustic sources,

- Underwater explosives and other underwater civil engineering activities,
- Airborne noise from supersonic aircraft.

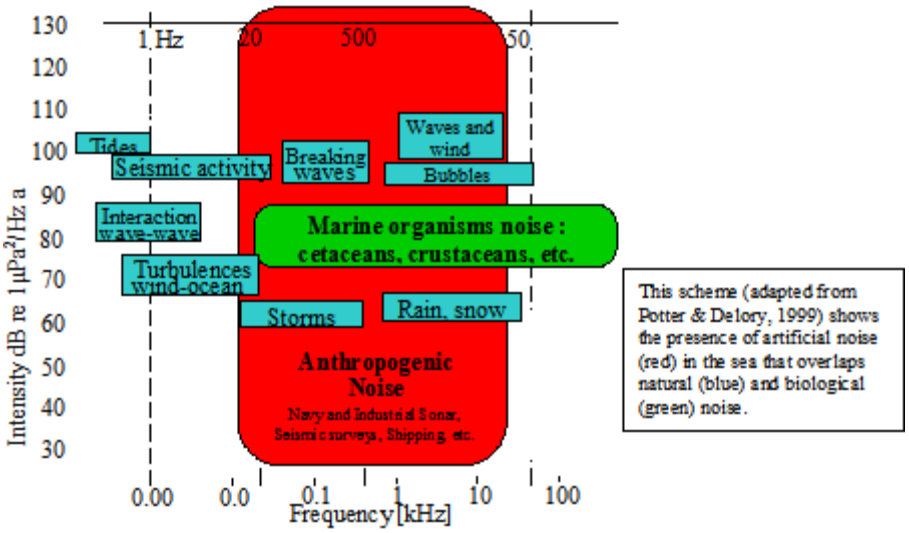


Fig. 73 Types of noise sources

The noises can cause lesions in the acoustic organs of cetaceans, which can result in displacement, avoidance reactions, collisions with ships, mass stranding and death.

Noise Sources	Sound Levels
Lightning strike on water surface	260 dB (approximately)
Seafloor volcanic eruption	255 dB (approximately)
Sperm Whale	163-180 dB
Fin Whale	160-186 dB
Humpback Whale	144-174 dB
Bowhead Whale	128-189 dB
Blue Whale	155-188 dB
Southern Right Whale	172-185 dB
Gray Whale	142-185 dB
Shipping	180 dB (approximately)
LFA (Low Frequency Sonar)	240 dB
Yachts and pleasure boats	160 dB
Military and industrial sonar	230 dB

All decibels (dB) are re 1 microPa at 1 m

Source: http://www.surtass-lfa-eis.com/Terms/index.htm**, 05-03-2010**

5.3 Internal analysis

5.3.1 Organisation

The need to control sea noise that is made by human activities in order to protect the cetaceans in the marine environment has resulted in the development of the Autonomous Acoustic Buoy. The AAB records and samples acoustic signals found in the

marine environment and then delivers them through a wireless connection to a computer. Scientists are then able to analyse the received information.

The Laboratori d'Aplicacions Bioacústiques (LAB) is an organisation which has desires to sell the technique of the AAB to other companies, in order to aid in the protection of the ocean environment.

The LAB was created with a grant from the Spanish Ministry and support from the city Vilanova i la Geltrú. A group of scientists are working together to increase awareness of the acoustic degradation of the marine habitat in the Mediterranean Sea and the North Atlantic. At this moment the organisation has thirteen employees. Although the final decision should be made by the director of the LAB, Michel André, each employee has their own activities and responsibilities. Most of the activities, which are needed to provide in the objective of the company, are carried out by employees of the LAB themselves. Activities include the following; research, design, acoustic identification of marine mammals, developing of methods for processing and automatic classification of hydrophone recordings and finally engineering.

5.3.2 Employees of the lab

An organization chart for the company can be found in the appendix, *[Appendix 17]*.

Michel André	-	Director
Josep Maria Alonso	-	Associated researcher
Cristina Álvarez Baquerizo	-	Specialist of environmental law, in particular the communitarian law. She is a legal adviser for nature's protection
James L. Aroyan	-	Associated researcher
Joan Vicent Castell	-	Senior scientist
Eduard Degollada	-	Associated researcher
Joaquín del Río	-	Acquisition of auditory evoked potentials in cetaceans
John C. Goold	-	Associated researcher
Ludwig Houégnigan	-	Developing processing techniques
Alex Mas	-	Researcher
Maria Morell	-	Researcher

Marta Nin i Camps	-	Design of scientific exhibits and research divulgation
Marta Solé	-	Biologic, pathology, anatomy
Mike van der Schaar	-	Acoustic identification of marine mammals
Serge Zaugg	-	Developing methods for processing and automatic classification of hydrophone recordings

The actual production of the buoy will be outsourced to two other companies. One company is located in Barcelona and the other one in Italy. These companies specialise in the production of buoys, although not only for the LAB but also for other companies.

5.3.3 Objectives and mission

The objective of the company is to create a system, the AAB, which investigates the sound production and reception in animals, including man, the biological acoustically-borne information transfer and its propagation in elastic media. With this system the LAB wants to protect the cetaceans in sea, because the noises of human activities can lead to the dead of animals. The company has the desire to be the first company with a system like this. This objective leads us to the mission of the company;

"Protect the environment, by providing tools to help human activities on the sea to continue, although without damaging the environment."

5.3.4 Target group

For companies it is important to decide who the target group is before introducing the product into the market. The AAB is a business orientated product, a business-to-business market. The target group for the AAB consists of companies with activities in the windmill industry, offshore oil and gas exploration and production, as well as navies.

5.3.5 Marketing mix

5.3.5.1 Product

To get information about cetaceans living in the marine environment, a product is needed that receives sounds from underwater sources. The AAB is able to receive sounds in an underwater environment by a hydrophone. The hydrophone is an element in the AAB which will pick up acoustic energy. The hydrophone will not only receive sounds from the cetaceans, but also from other animals, natural sources like waves, rain, storm and human activities. To make sure that only the sounds of cetaceans will be saved, a filter is needed. The filtering and amplifying of the signal is done by the Programmable Filtering Circuit (PFC). After this step, the information will be sent to the Hercules Board, a computer which is installed in the AAB. This computer controls the gain and cut-off frequencies of the PFC. Beside that the Hercules Board will sample and sent the recorded signals to a computer, through a wireless internet

connection. After receiving the signals from the AAB, the employees of the LAB can study the information[3].

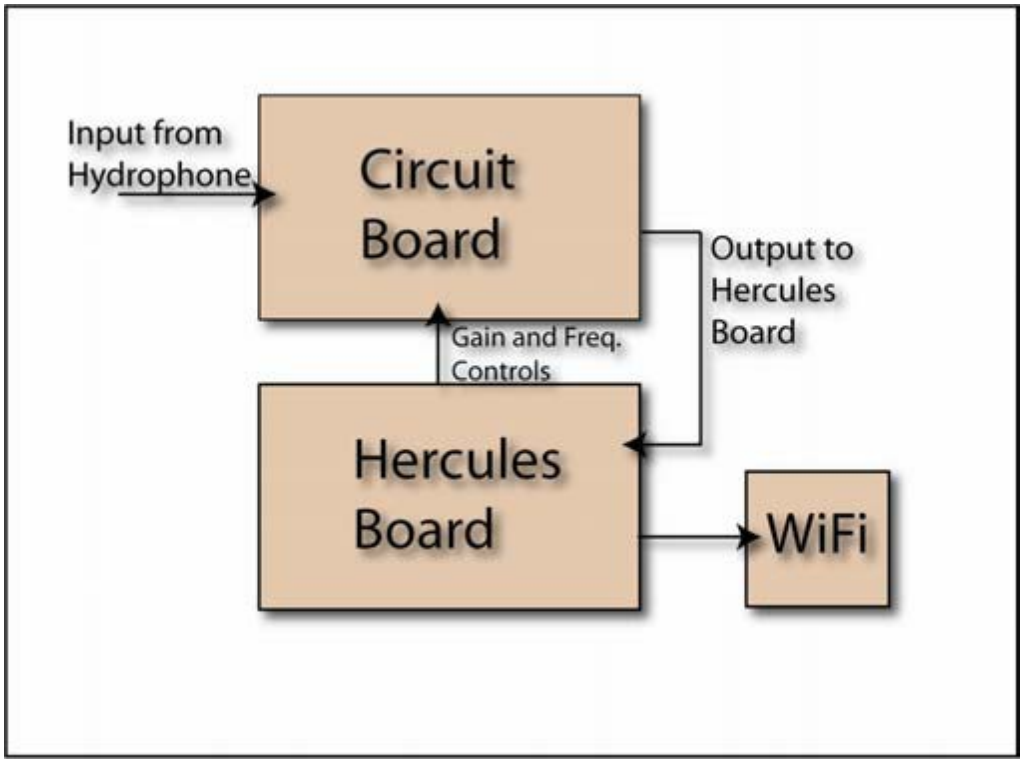


Fig. 74 Basic Block diagram of the AAB; Source: Final report AAB for the EPS, 2008-2009

The Autonomous Acoustic Buoy is a new product on the market, in other words: the product is at the orientation stage of the product life cycle. An advantage of this stage is that there aren't many competitors on the market. Although it is important to bring the product to the next stage in the product life cycle through its disclosure to potential customers. As result of this disclosure, sales will increase and will take the product to the next stage known as growth. A promotion campaign is very effective at this stage of the cycle.

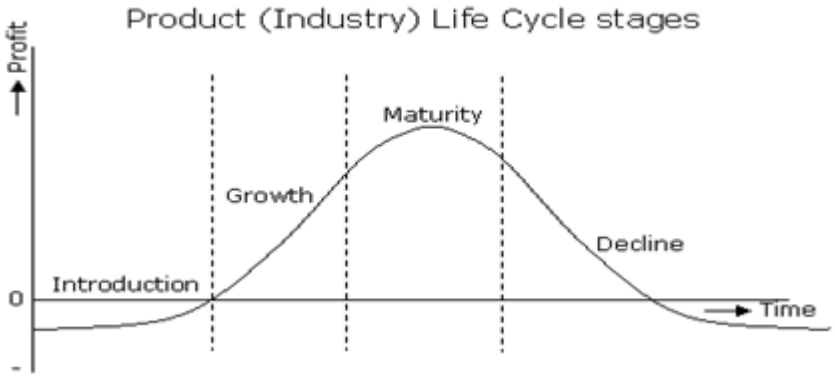


Fig. 75 Product Life Cycle stages

At the moment the product is ready for sale, although the company is still making further improvements to the system.

5.3.5.2 Price

The company have not yet decided the price.

5.3.5.3 Place

The Autonomous acoustic buoy is a product that has a global coverage. This is a result of the target group on which they are focussing for example the windmill industry and navies. These are examples of organisations which are operating on a global level.

5.3.6 Financial situation

The LAB doesn't have many financial resources. At the moment they are busy with providing the system. This marketing plan has to introduce the AAB on the market in order to find customers and investors.

"Sons de Mar needs your support through a donation

To collaborate with Sons de Mar is to decide to actively participate in the conservation of the ocean's balance. As an individual, or from your company. It is an investment in dedicated research; it is the desire for sustainable development in the sea, now, and for the generations to come.

The decision to help the sea getting back to its own environment of natural sounds, without noise pollution, is a choice everyone can make."

5.4 External analysis

5.4.1 Economic

According to a report of PricewaterhouseCoopers LLP there is a political revolution on its way, this which will change the leading economic countries. At this moment the USA, Japan, Germany, France, United Kingdom, Italy and Canada (G7) are the leading countries. Although they will be challenged by a new group, the E7, China, Russia, India, Brazil, Mexico, Indonesia and Turkey. By approximately 2019 the average GDP (Gross Domestic Product) of the E7 will match the GDP of the G7. However by 2023 it is expected that the GDP of the E7 will have increased and would then be higher than the GDP of G7 by 30%. In 2030 the global priority list of the most important global economies will consist of: China, USA, India, Brazil, Russia, Germany, Mexico, France and United Kingdom[44].

5.4.1.1 Europe

An article on the website www.express.be, "Eurozone Forecast" by Ernst & Young states that the European economy will be weak until 2012. By this point most of the larger member states would have overcome the recession however the prospects in the short term are problematic. The GDP will increase by 1% in 2010 with a 1.6%

increase in 2011. This is n contrast with unemployment rates which will reach a peak of 17 million unemployed people (10,3% of the labour force). The worst part of the recession has already passed by, although it is not over yet and we won't see a full recovery until at least 2012. The expectation is that the north of Europe (Germany, France and the Benelux) will recover faster than the south of Europe (Greece, Portugal, Spain, Ireland and Italy). The economy will only increase by 0,6% from 2010 to 2012, in comparison with 1,8% for the north of Europe. A result of this there is a gap between the north and south of Europe[45].

5.4.1.2 America

Since 2009 the economy of America is growing. This is a result of the increased export of 18% in 2009. At the fourth quarter of the year the American economy grew with a 5,9% base year on year. The GDP increased with 2,2% base year on year in the third quarter of the year. If we look at the GDP in 2009, as a complete year, it has decreased by 2,4%. This is the largest decrease since the decrease of 10,9% in 1946.

The total amount of income of companies, consumers and government in American was 13.14 billion dollars in the fourth quarter of 2008. One year later this had already increased to 13.16 billion dollars. Unfortunately the expectations are that this increase will not continue. As soon as the stimulus money of the American government is out of the market, it is expected that consumer expansion will decrease[46].

In April consumers trust in the economy greatly decreased. Index figures show that consumers lost is trust for example 73.6 in March to 69.5 in April. Although analysts thought that the trust would increase instead of decrease. According to research consumers are insecure about the weak labour market and their own job certainty. Beside this consumers lost their faith in the economic policy[47].

This was not the only change in March, the consumer price index also increased. In comparison with the previous month it increased by 0,1%[48].

5.4.1.3 Africa

This year the world cup will be held in South Africa. The success of the world cup is crucial for the economy of the country. At the moment Africa is one of the world's poorest inhabited continents. Like other countries in the world, South Africa also suffered from the worldwide recession last year. The economy decreased in 2009 by 1,8% and 900,000 jobs were lost. However the minister of Finance expects a growth in 2010 of 2.3% largely due to the world cup football. If predictions are correct the South African economy will be better in 2012. Also if we look at the figures of the years before 2008, this period saw the economy grow by 5% a year[49].

5.4.1.4 Asia

An article published in April 2010 predicted that upcoming economies in Asia would grow by 7.5% this year, a forecast from the Asian Development Bank (ADB).

Last year the GDP of Asia grew by 5.2%. For 2011 the ADB expects a growth of 7.3%. It is predicted that China will be the leader of these upcoming economies, with a growth in GDP of 9.6%. It is expected that china would first be followed by Azerbaijan with an increase (9.5%) and then India at (8.2%). Only the economy of Fiji will decrease this year.

These positive figures are a result of the rising incomes and stimulation policies of the government. This will also result in an inflation growth of 4% in 2010. For 2011 a growth of 3.9% is expected.[50]

5.4.2 Social - cultural

During internet searches about ocean noise, a lot of articles were found. Articles with the subjects such as: increasing of sea noise, stranding whales, increasing of offshore activities and so on.

The following texts are a short preview of articles found:

“Whale songs drowned out by human noise pollution”, is the title of an article posted on October 29, 2009 by LKBlog. The article writes about the increasing of sound pollution, and claims that this is not only confusing the mammals, but that it is also threatening the survival of these endangered animals. At one point cetaceans were able to communicate over thousands of miles and now they are losing touch with each other. This text is taken from a speech made by an expert during a conference in Rome. That same period, 100 governments were gathered in Rome for a meeting of the U.N.-backed Convention on the Conservation of Migratory Species of Wild Animals. The agenda of this meeting includes ways to increase protection for endangered species, including measures to mitigate under water noise[51].

Another article was found with the title: “Whale strandings sounding alarms in NZ & Italy”. This article was published on December 28, 2009 also by LKBlog. About 30 whales were stranded on Coromandel peninsula. Experts are studying cases like this. They believe that cetaceans are becoming beached as a direct result of an increase in sound pollution within the marine environment[52].

Human activities on oceans and seas are increasing; this results in an increase in sea noise. Take for example the offshore industry, in the last two years more offshore wells have been drilled than the rest of the decade combined. Between January 2008 and July 2009 35 on- and offshore wells were drilled, and this is only a short period[53]. Another example is seaborne transportation, in other words: shipping. “According to HELCOM, around 2000 ships are normally at sea at any time on the Baltic Sea [54].” The expectations are that this form of transportation will increase by 40% by the year 2017.

The last example article is about important progress in field of the legislation. Environment group IFAW posted on March 15, 2010 an article with the title: “Senator John Kerry introduces legislation to protect whales”. With this action the Senator John Kerry (D-MA) shows his commitment towards environmental conservations. The ‘International Whale Conservation and Protection Act of 2010’ addresses major threats to whales including commercial whaling, ship strikes, entanglement in fishing gear, ocean noise, and climate change and reasserts the U.S. as a leader in whale conservation. Jeff Flocken, DC Office Director of IFAW, hopes that other Senators will follow after this step.

Elements of the legislation include:

- Promoting international efforts to conserve and protect the world’s whales throughout their range.
- Strengthening the whale conservation and protection efforts of relevant international organizations including the United Nations Convention on the Conservation of Migratory Species of Wild Animals, the International Whaling Commission (IWC), the Convention on International Trade in Endangered Species (CITES), and the International Maritime Organization.
- Ensuring that the IWC commercial whaling ban is neither lifted nor weakened and that the related illegal and lethal scientific whaling is ended.
- Reducing and, where possible, eliminating sources of human caused death, injury, harassment and disturbance of the world’s whales.
- Initiating and expanding research to improve our understanding of the world’s whales including health and reproduction, whale habitats and the impacts of human activities and other threats to whales [55].

Nowadays it is more and more important for the society that people and companies are environmentally responsible. There are legal environmental requirements and regulations for companies.

Environment

Companies are required to take care of their activities, to cause less harm to the environment. For example by taking care of their refuse in addition to conserving natural resources and reducing the amount of greenhouse gases expelled from their activities. An environment-friendly management system seems expensive in the short term, although it will pay off on the long term. It will improve the competitive position of companies on the market.

Employees

With regards to employees companies have obligations. It is their job to prevent discrimination at work. Beside that the work surroundings have to be safe and healthy for employees.

Voluntary action

All companies have to satisfy to the minimum legal requirements, although thinking ahead can improve their position on the market. It will contribute to a better competitive position, making company activities more long lasting and also increasing the chance of economic success on the long term [56].

Justifying undertaking is crucial to build faith, trade and globalisation [57].

5.4.3 Political-juridical

Companies are having a big influence on the environment. This influence is the most important reason why they have to conform to a lot of EU environmental restrictions. Examples of restrictions are in air quality, chemical matter and waste management.

The EU has setup an environment programme, consisting of six aspects to protect the environment. The six aspects are:

- Less pollution
- Suppression of climate change
- Maintenance of bio-diversity
- Respecting natural resources
- Minimising amount of greenhouse gases expelled
- Taking responsibility for the disposal of chemical matter

5.4.4 Customer analysis

There are three kinds of businesses which are interesting for the LAB to focus on.
Firstly the windmill industry:

5.4.4.1 Windmill industry

Two European innovators worked together to create wind turbines that can float on the ocean's surface. One of the innovators is a company from Norway, Norsk Hydro, and the other one is from Germany, Siemens [57].

Norsk Hydro

Hydro is a Norwegian energy group, a major energy producer. Hydro's

energy expertises are:

- Comprising both energy production and trading
- Is vital to us in our role as the biggest aluminium producer in Europe
- It is crucial that we assess the likelihood of constancy in the regulations governing new projects

The mission of Hydro is to contribute to a more viable society. This means that they lead the creation of conditions that help others develop and progress. Our mission implies certain values which govern our behaviour, both as individuals and as organization. The mission leads to the values: courage, respect, cooperation, determination and foresight.

Hydro is aware of the climate change on the planet, from emissions of greenhouse gases. That is the reason why the company committed to create systems and technologies to reduce those emissions.

Siemens

Siemens is a German engineering company with a straight and clear mission. They want to find the best way of combining and developing their know-how and expertise, so that they can profitably channel them into outstanding value for customers. Highest performance with the highest ethics, this is in one sentence the value of the company. Although they have three other words which are important: responsible, excellent, and innovative. Responsibility is important because of the commitment to ethical and responsible actions. They want to be excellent in high performances and results, and being innovative to create sustainable value [59].

5.4.4.2 Oil/gas industry

The oil and gas industry is comprised of a few large companies which are operating worldwide. Beside these big companies there are a lot smaller companies. In other words: the oil/gas industry comprises a lot of companies. The question is, which organisations are potential customers for the LAB?

Shell

Shell is a global energy and petrochemical company. The aim of the company is to meet the energy needs of society, in ways that are economically, socially and environmentally viable, now and in the future.

Sustainable development is integrated in the organisation of Shell. The main activity is to help meet the world's growing energy needs, although this is a damaging activity for the environment. Shell tries to reduce impacts of their operations, including tackling greenhouse gas emissions. As a global energy company they set high standards of performance and ethical behaviours. Shell is aware of the fact that there reputation is

depending by how they live up to their core values: honestly, integrity and respect for people. People judge on the way the company act.

The strategy of Shell is: “More upstream, profitable downstream”. They are focusing on delivery and growth, leveraging their strong portfolio[60].

BP

Like shell, BP is a global energy and petrochemical company. The company wants to be recognized as a great organisation, competitively successful and a force for progress. They believe that they can make a difference in the world, by helping the world meet its growing need for heat, light and mobility. The activities are on a way that it is affordable, secure and doesn’t damage the environment.

The values of the company are: progressive, responsible, innovative and performance driven. Progressive; in the way they build relationships. For the company it is not only important to build on a good relationship between employees, but also with their partners and customers. They believe in the principle of mutual advantage. Responsible; the company feels responsible for the safety and development of their employees and the communities and societies in which they operate. Innovative; they push boundaries today and create tomorrow’s breakthroughs through their people and technology. Performance driven; they deliver on their promises through continuous improvement and safe, reliable operations.

The strategy of BP is separated into three fields:

- Explore for, develop and produce more fossil fuel resources that the world needs.
- Efficiently manufacture, process and deliver better and more advanced products.
- Be a material contributor to the transition to a low-carbon future.

They want to strengthen their position further by securing new access and achieving exploration success [61].

Hess

Hess is a leading global independent energy company, engaged in the exploration and production of crude oil and natural gas, as well as in refining and in marketing refined petroleum products, natural gas and electricity.

The vision of the company is to maximize shareholders value by enhancing financial performance and providing long-term profitable growth. They are committed to meet the highest standards of corporate citizenship by protecting the health and safety of

their employees, safeguarding the environment and creating a long-lasting, positive impact on the communities in which they do business.

The company has operations worldwide. The countries they are operating are: the United States, United Kingdom, Norway, Denmark, Russia, Equatorial Guinea, Algeria, Libya, Gabon, Egypt, Ghana, the Joint Development Area of Malaysia and Thailand, Indonesia, Thailand, Azerbaijan, Australia, Brazil and St. Lucia.

The marketing and refining objective is to maximize financial returns from existing assets. The Company operates about 1,360 Hess branded sites in 16 states along the East Coast of the United States. They continue to selectively expand our HESS EXPRESS convenience store network. The HOVENSA refinery in the United States Virgin Islands, a joint venture between a subsidiary of Hess Corporation and a subsidiary of Petroleos de Venezuela, S.A. (PDVSA), is one of the largest crude oil refineries in the world. Refined petroleum products, as well as natural gas and electricity, are marketed to customers throughout the East Coast of the United States. This integrated approach to marketing allows the Company to meet the total energy needs of our customer base while maintaining a low-cost operating base. They have a strong leadership team and a global organization, implementing a focused strategy that is positioning Hess Corporation for long-term financial performance.

The values of the company are: integrity, performance, social responsibility, independent spirit and value creation [80].

Maersk

Maersk group is a global company, which operates in 130 countries and has a workforce of 120,000 employees. In addition to owning one of the world's largest shipping companies, they are involved in a wide range of activities in the energy, logistics, retail and manufacturing industries.

The values form a guiding principle for behaviour, decision making and interaction, a set of fundamental shared beliefs.

Constant care, take care of today, actively prepare for tomorrow.

Humbleness, listen, learn, share, and give space to others.

Uprightness, our word is our bond.

Our Employees, the right environment for the right people.

Our Name, the sum of our values: passionately striving higherc[81].

One of the business areas is oil; Maersk Oil. This branch of the company is specialized in offshore oil and gas production. The values of Maerks Oil are the same as the other branches of the company, although the objectives are not. It is Maersk Oil's objective to identify, control and minimize emissions, discharges and wastes from exploration and production activities. Offshore oil and gas production can affect the environment

in various ways; for example, offshore energy requirements are normally provided by the combustion of natural gas, which results in emissions to the atmosphere. Another example is the water, produced with oil and gas, which is discharged to sea after cleaning. Because of the damaged offshore oil and gas production can cause feels the company committed to protect the environment and places high priority on environmental considerations. Through constant care – careful use of resources, optimization of operations, and handling of waste streams – minimize the environmental impact of activities. Beside that the company strives for continental improvement in the environmental performance and pollution prevention across all the activities. This involves openness, environmental awareness, and the application of environmentally-friendly technologies.

5.5 SWOT-analysis

To indicate the relevance of the strengths, weaknesses, opportunities and threats is worked with marks. The higher the mark, the more important the strength, weakness, opportunity or threat is.

1 = Less than average
2 = Average
3 = More than average

5.5.1 Strengths	**Relevance**	**Section**
• S1: Clear objectives and a clear mission	2	5.3.3
• S2: Protecting the marine environment	3	5.3.1
5.5.2 Weaknesses		
• W1: Not yet a price definition for the AAB	3	5.3.5
• W2: A lack of financial sources	3	5.3.6
• W3: Factory also produces for other companies	2	5.3.2
• W4: Product needs still some improvements	1	5.3.5
5.5.3 Opportunities		
• O1: Increasing of interest in the problem	3	5.4.2
• O2: Because we past the worst part of the recession, there is space for other problems	3	5.4.1
• O3: Environmental responsibility is important for society	2	5.4.2

- O4: Big companies are trying harder to be environmentally responsible 3 5.4.4

5.5.4 Threats

- T1: Companies aren't obligated to protect the marine 1 5.4.3
- T2: It is hard to get attention from companies 3 5.4.3

5.6 Confrontation matrix

The strengths, weaknesses, opportunities and threats from the last chapter are presented in the confrontation matrix below. A confrontation matrix provides insight into the possibilities to combine strengths and weaknesses with opportunities and threats. One plus (+) indicates a relative context between strength 1 and opportunity 1, for example. The blue colour indicates a strong correlation between the selected points. A strong correlation between two points can be the basis for a strategic strategy, to give direction to the company.

Table 16 Confrontation matrix

		Opportunities				Threats	
		O1 (3)	O2 (3)	O3 (2)	O4 (3)	T1 (1)	T2 (3)
Strenghts	S1 (2)	+	-	-	-	- -	+
	S2 (3)	+ +	+	+ +	+ +	+ +	+
Weaknesses	W1 (3)	+	+	-	-	- -	+ +
	W2 (3)	+ +	+	+	+	+	+
	W3 (2)	+	- -	- -	+	- -	- -
	W4 (1)	+	+	- -	+ +	- -	+

+ +	Relatively high context
+	Relative context
-	No relative context
- -	No relative context at all

5.6.1 Strategic option 1

S2 + O1 or O4 = take advantage of the strength and opportunity

S2: Protecting the marine environment

O1: Increasing of interest in the problem

O4: Big companies are trying harder to be environmentally responsible

A strength of the LAB is the desire to protect the marine environment. For the society it is more and more important that companies are operating in an environmentally responsible way. This is a result of the deterioration of the environment, and the predictions that it will be worse if nothing were to change. This opportunity indicates that there is a market for the AAB. From this point it is important to take advantage of the opportunity; “Big companies are trying harder to be environmentally responsible”. By offering companies a solution to be environmentally responsible with the marine environment.

The first step is to make contact with potential customers. There are a lot of different marketing-communication instruments to communicate with customers. For example: public relations, advertising, direct marketing, sponsoring, fairs, in store-communication or personal sales. Because of the lack of financial resources it is not possible to use different kinds of marketing communication instruments. Direct marketing and personal sales are two marketing tools that could be used to get the right result, without high costs. For the content of the message is it important to focus on the advantages for the company.

The post brings everyday a lot of advertisement letters and flyers. This results decreased interest from receivers. However, receivers of addressed mail will read the letter or flyer more carefully. This is an important advantage of direct marketing. The LAB could send potential customers a letter, with information about the solution they offer to protect the marine environment against ocean noise. This letter should be sent including with the flyer of the AAB, also with a request to come to their company to give a short presentation about the product and what the advantages are for the company. The presentation is an example of personal sales. An important advantage of personal sales is the opportunity to customize the story to the needs of the customer, answer their question immediately and take away their uncertainties.

5.6.2 Strategic option 2

W1 + T2 = Avoid or pull back
W1: Not yet a price definition for the AAB
T2: It is hard to get attention from companies

Nowadays it is hard to get attention from companies, especially from big companies who are operating worldwide. Without complete information it is even harder to get their attention. Before further contact with companies it is recommended to define a price for the AAB.

There are two different price strategies that are recommended for the LAB: Skimming pricing and penetration pricing. Skimming pricing means that the product would be introduced on the market with a high price. As soon as the sales are decreasing, the price would be slightly reduced. Penetration pricing is the opposite. Firstly, the product

is introduced into the market with a low price to attract customers. Afterwards, the company will slightly raise the price.

5.6.3 Strategic option 3

W2 + O1 = Improve or transform weaknesses into strength
W2: A lack of financial sources
O1: Increasing of interest in the problem

An increasing of interest in ocean noise can influence the position of the LAB positively. Although, the LAB doesn´t have any brand awareness at the moment. As long as the potential customer doesn´t know about the existing of the company, they will not sell anything. That is the reason why it is important to get brand awareness. Marketing is a tool that would generate awareness by potential customers. Because of the weakness, a lack of financial sources, it is not easy to create a marketing campaign. These weaknesses should be first improved or transformed into a strength. Improving the weakness into a strength would give the LAB a stronger position.

There is one marketing-communication instrument that is suitable to implement strategic option 3, Public Relations (PR). With PR it is possible to generate free publicity. To create free publicity it is important to get attention from journalists from papers and trade journals. As soon as they write about the idea of the LAB and its product, it will result in brand awareness in the market. Followed by an increased interest from potential customers, what can result in demand of the AAB.

5.7 Chosen strategy

After a lot of research and with help from the confrontation matrix, it is recommended to choose strategic option 1, “take advantage of the strength and opportunity”. In this chapter an example of the direct communication and the personal sales is presented.

5.7.1 General letter

Dear Sir / Madam,

I am the head of the Laboratory of Applied Bioacoustics of the Technical University of Catalonia, in Spain. Our laboratory main objective is the development of technological solutions to balance the effects of anthropogenic sound sources on the marine environment and to provide interested parties with real-time mitigation tools when faced with the necessity of detecting, identifying and localizing sound sources, in particular cetacean acoustic signals, in areas of interest.

Geophysical prospection is often associated with the production of loud noise that may have a detrimental effect of near-by individual cetaceans. The challenge in this situation is to be able to monitor the presence of these animals continuously and immediately determine the actions to be undertaken.

Our laboratory has developed a totally automated system that is supported by low-cost autonomous buoys that can be deployed during seismic surveys. These buoys are radio-linked to the operating vessels and transmit in real-time the position and movement of any individual cetacean around the boat.

We believe this system would allow your company to sustainably develop its market.

I would be very happy to introduce to you and to your technical staff the characteristics of our system and answer any question you may have.

Your sincerely,

5.7.2 Letter Maersk

Every organisation and every company is different. To respond to the needs of the potential customer, it is important to customize the content of the message. The message should match the needs of the receiver to get their attention.

The letter below is an example of a letter for the company Maersk.

Dear Sir / Madame,

This letter is not written to blame you for your activities in the marine environment. It is also not our intention to disturb your work, in comparing to activists. However, we did write this letter to offer you a solution to reduce the damage of your activities to make sure that you can continue your businesses. Not only for the short-term but also in the future. A solution without blames, high costs or negative publication. In spite of these negative points, the solution to decrease excessive sea noise could give you advantages.

Information on your website showed that you already made some efforts to purchase low-noise technology. It is a good start, unfortunately it doesn't solve the problem completely. Like you, also the government, activists and the society are spending more and more time on the problem. Consequently, they will introduce more areas as Marine Protected Areas. Areas which are important for your activities can be turned into a protected area. By introducing the Autonomous Acoustic Buoy, our solution for this problem, you will evade this result.

We would love to sum up the benefits and give you an idea of the product during a short presentation at your office.

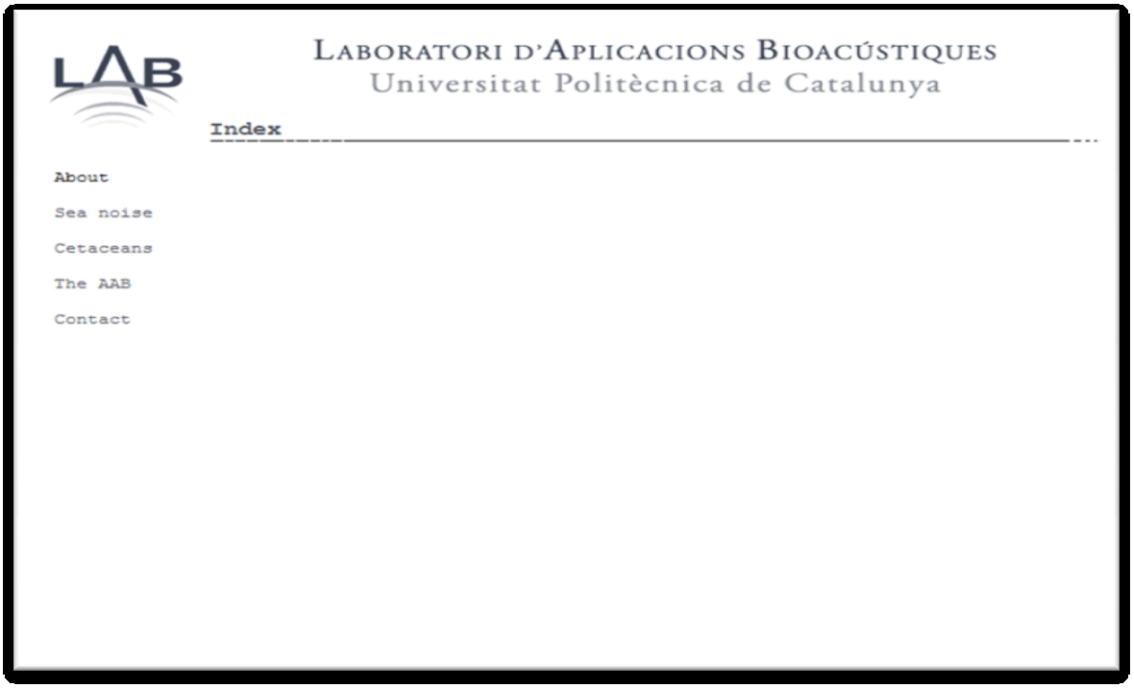
Thinking ahead will give your company opportunities, a strong position on the market in comparing to competitors and more profit from the society. These are just a few examples of benefits.

If you have any questions, don´t hesitate to contact us. We will call you next week to make an appointment.

Your sincerely,

5.7.3 Presentation

Personal sales are another marketing-communication instrument, which are recommended. In this chapter an example is presented of the layout for a presentation. It is important to use the same layout for all communication methods. If you use different layouts the customer will get confused. This is the reason that the layout of the website has been used for the presentation.



6. Conclusion

Over the course of the EPS comprehensive progress has been made in the development of the AAB. Each team member has worked to the best of their abilities in order to achieve their individual goals. This has resulted in an efficient and dynamic team working together to successfully further advance and develop the Autonomous Acoustic Buoy. The research and analysis system produced in the Dolphin Whistles Analysis section will allow the LAB team to more accurately and efficiently Identify different species of Dolphins by the sounds they produce. Both the information collected and analysis performed will allow the LAB to improve their understanding of cetaceans abilities to communicate underwater. For future work a more comprehensive analysis system could be designed.

For the electronics section, an efficient *watchdog* system has been designed and manufactured. This will allow the Autonomous Acoustic Buoy to become a self-reliant entity saving users from the need for direct intervention and thus time and money. The *Watchdog* system has been tested to be efficient in operation and can therefore be deemed as a success. However possible future improvements may include upgrading it by adding additional or more accurate sensors as well as software improvements.

CAD simulations carried out over the course of the project have enabled conclusions to be drawn about the overall stability of the Autonomous Acoustic Buoy. This has been carried out using both Computer software and theoretical calculations. In addition to initial requirements a computerised animation has also been produced in order to aid in the marketing presentation. In future a more detailed computer model could be simulated using software with greater processing capabilities; this would give a more accurate representation of the buoys behaviour.

The Marketing section has produced a detailed Marketing plan despite having to overcome difficulties in sourcing detailed information. However due to a lack of financial resources and cooperation of interested parties it has not been possible to write an entire marketing campaign. If the LAB wish to be able to put the Buoy on the market in future they first need to sail the buoy and present to companies. This will enable them to achieve financial backing and therefore a presentation has been designed. Once financial backing has been achieved the remainder of the marketing campaign can be designed.

Although further improvements have been outlined in this report these are minimal. Both the technical and analysis capabilities of the buoy have been significantly improved in addition to providing the LAB with guidance on how to enter the market. Overall the team is satisfied with the work undertaken and progress made. In addition the team have gone some way in helping the *AAB to* becoming the key to a sustainable solution for the protection of cetaceans against human activities in the marine environment.

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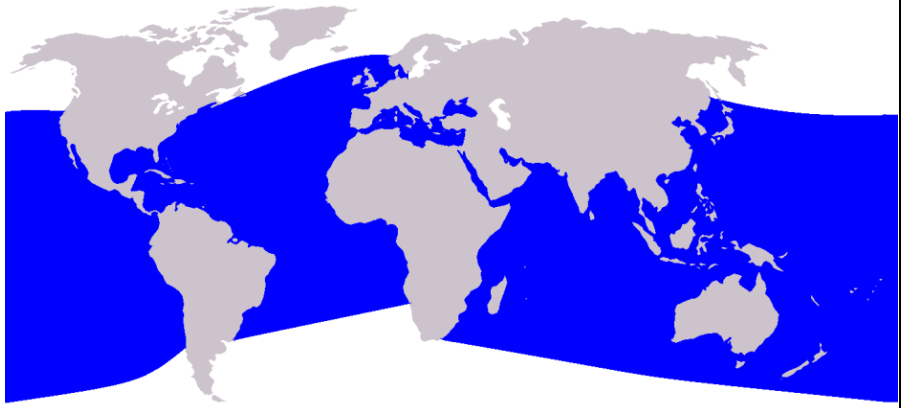
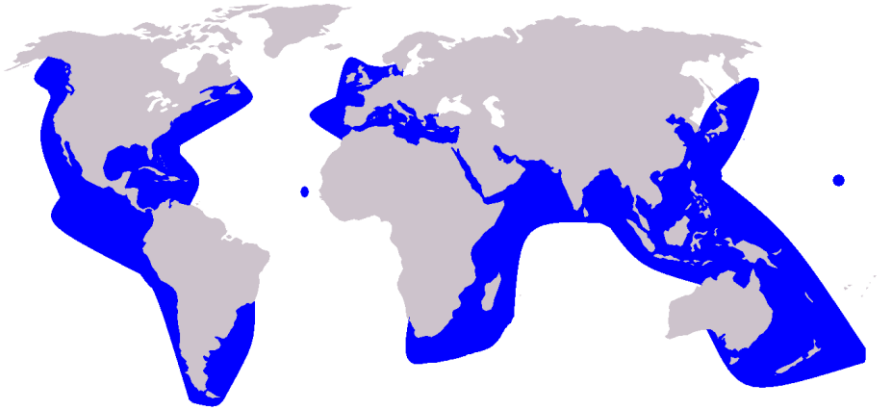
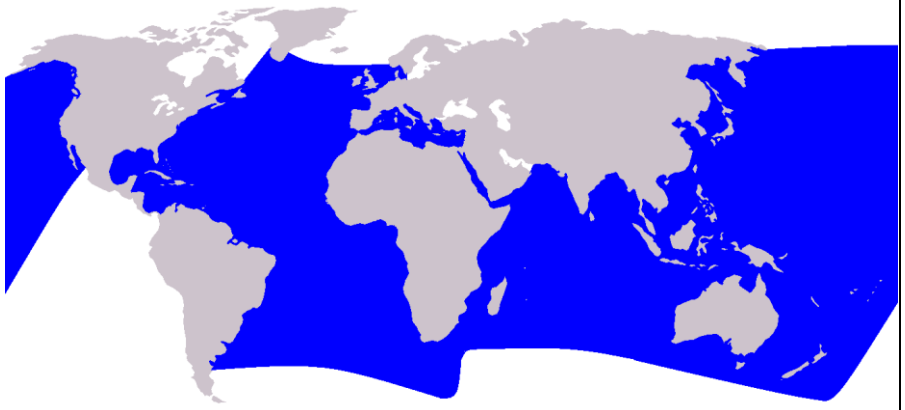
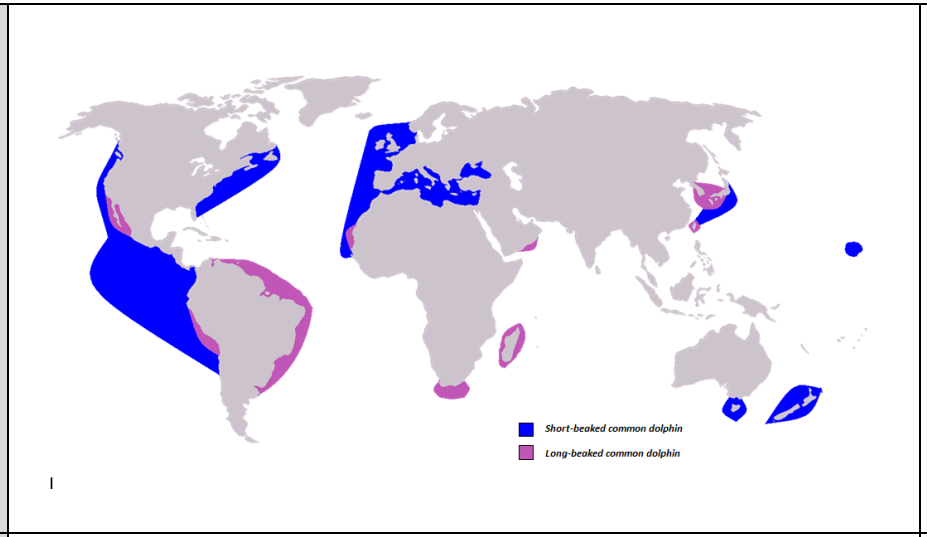
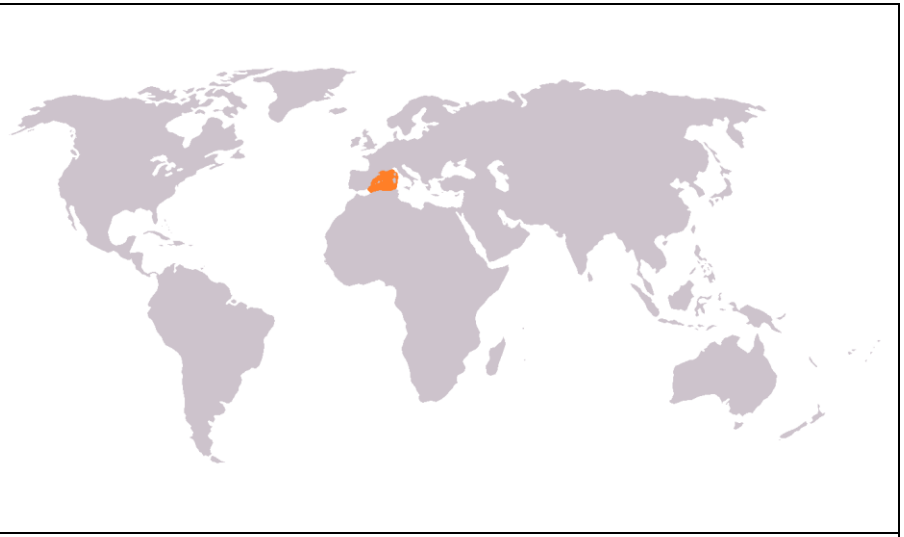
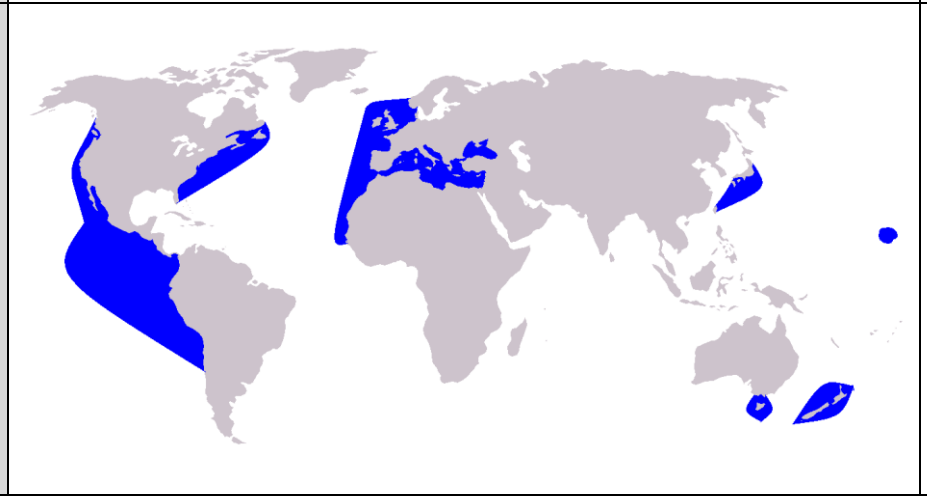
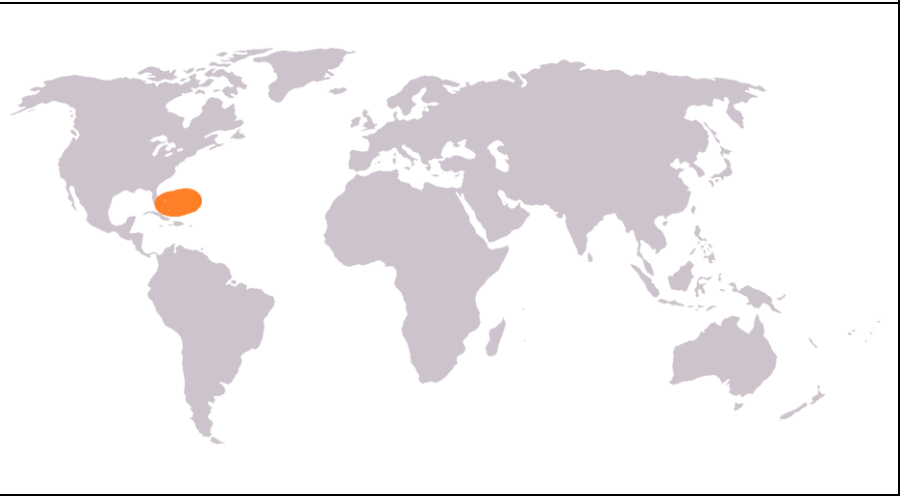
8. Appendix

Appendix 1: Geographic location table

Table 17: Geographic location list of species abundance in the Atlantic region section and the corresponding areas of examination of a given specie

	Geographic location	Area of examination
Bottlenose dolphin		

Risso's dolphin		
Striped dolphin		

Common dolphin		
Atlantic spotted		

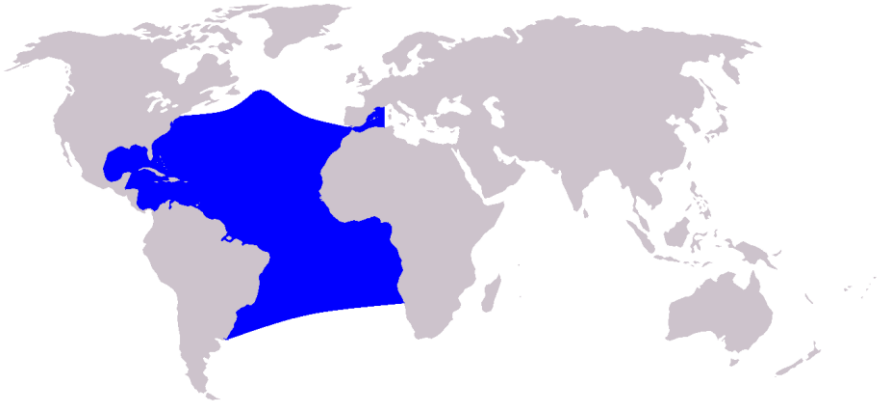
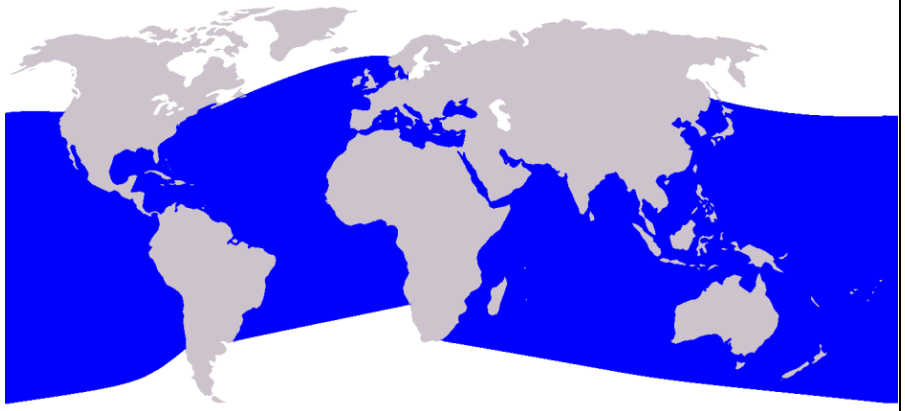
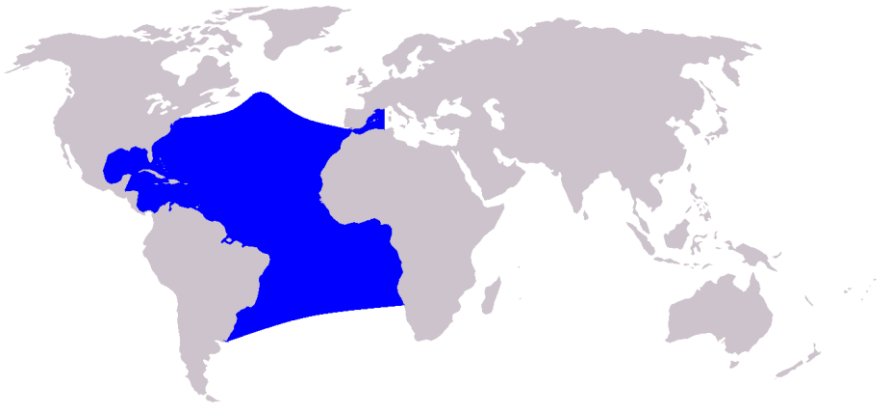
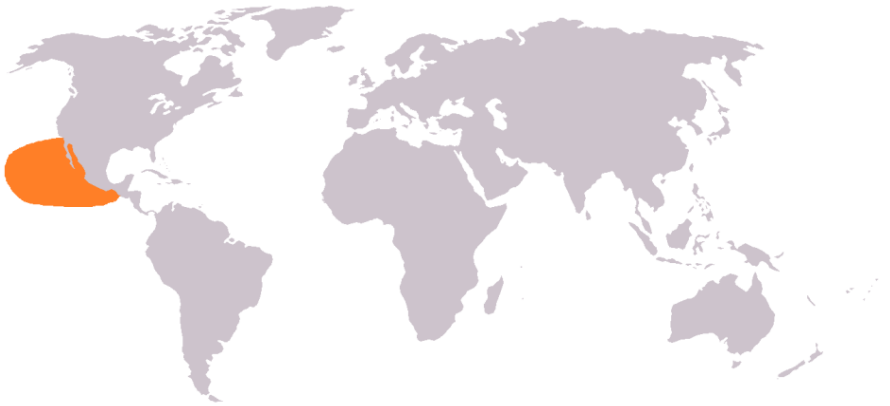
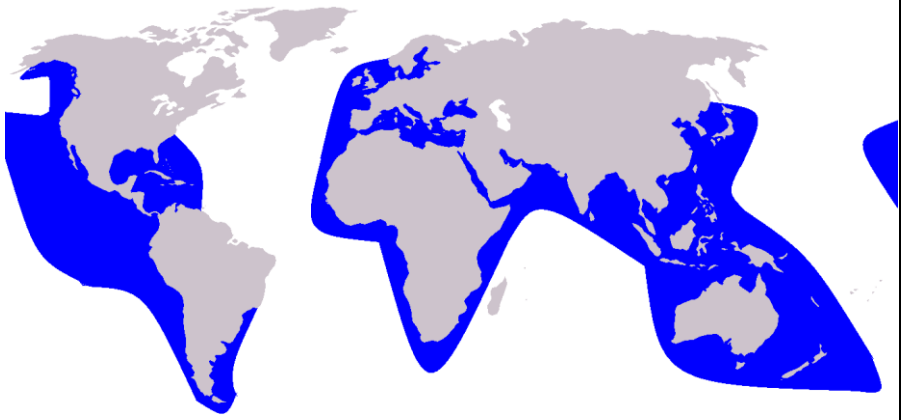
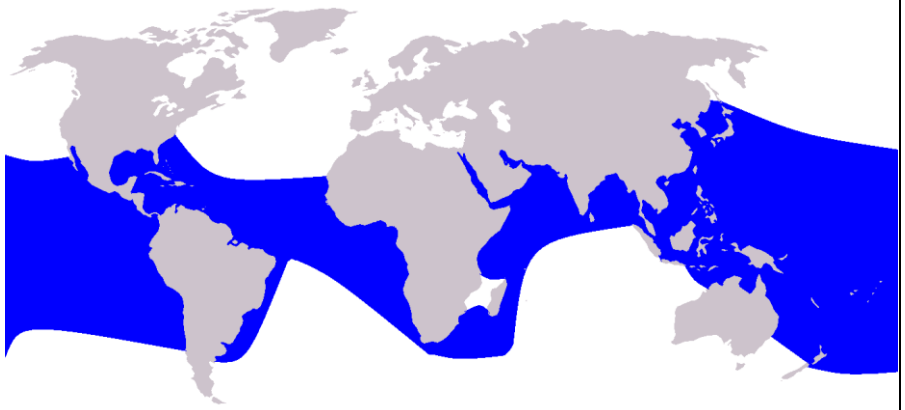
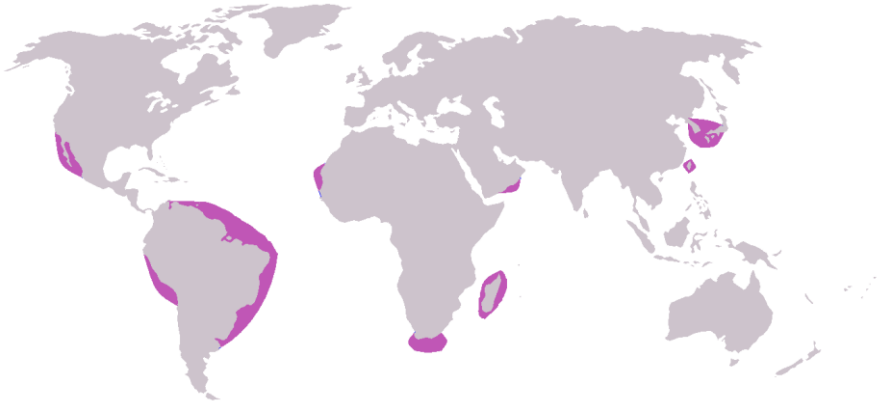
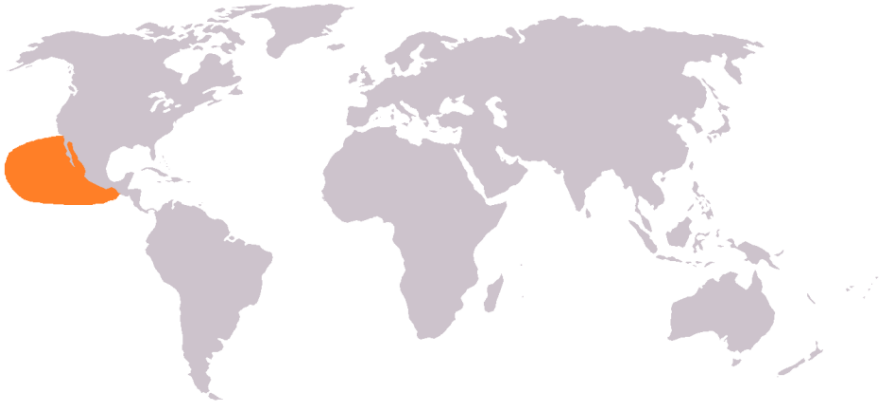
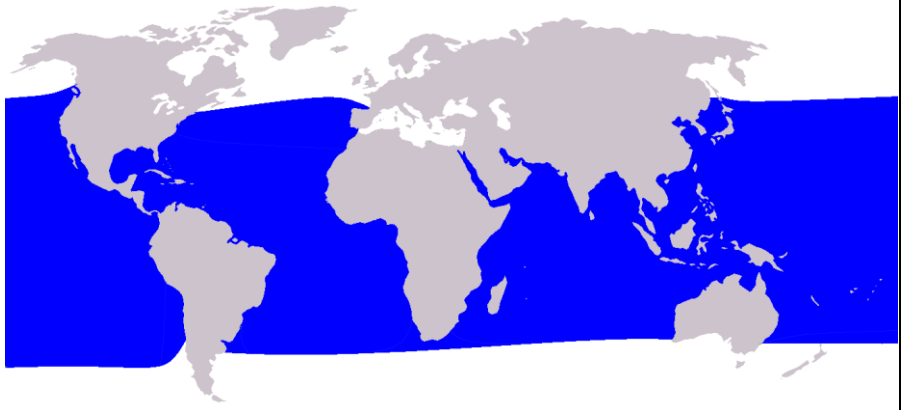
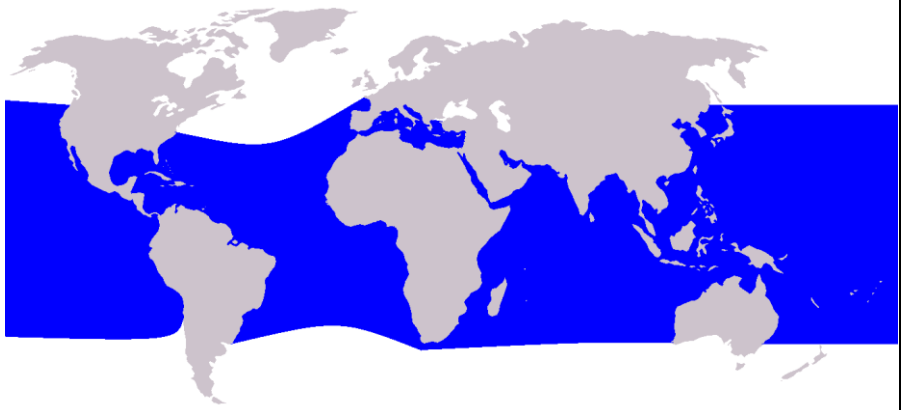
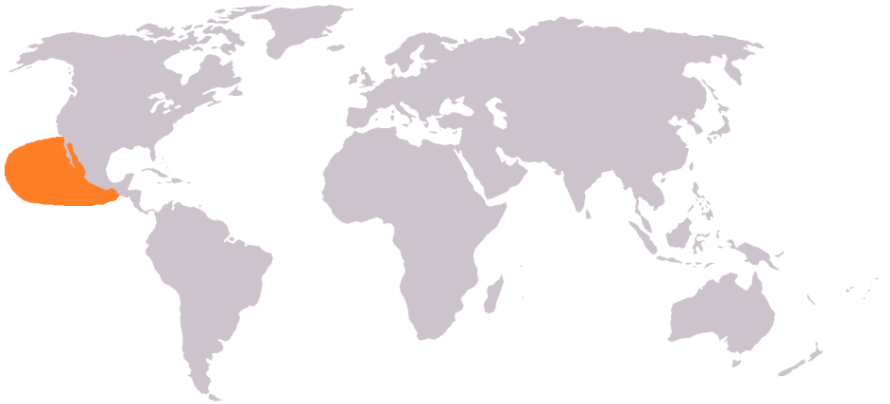
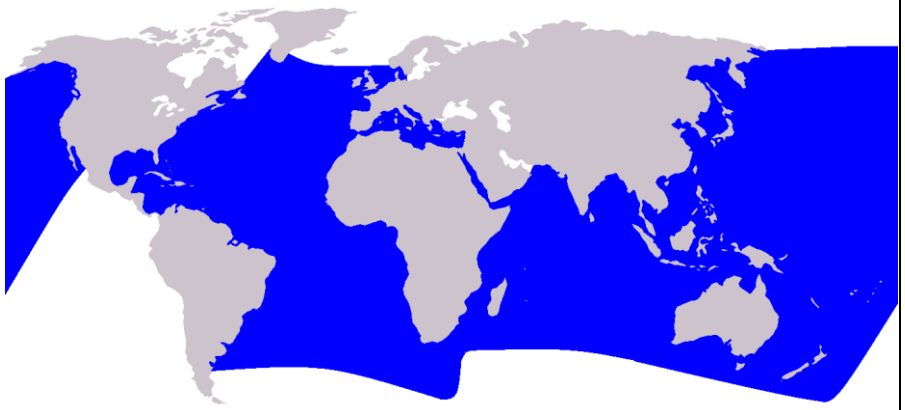
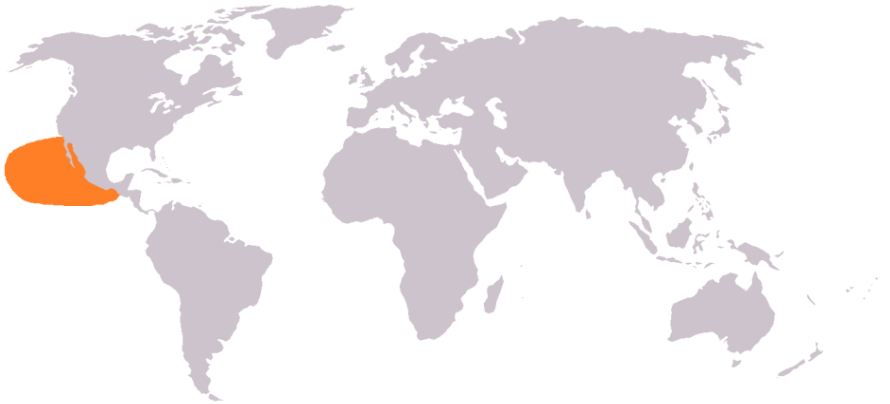
Short-beaked common dolphin		

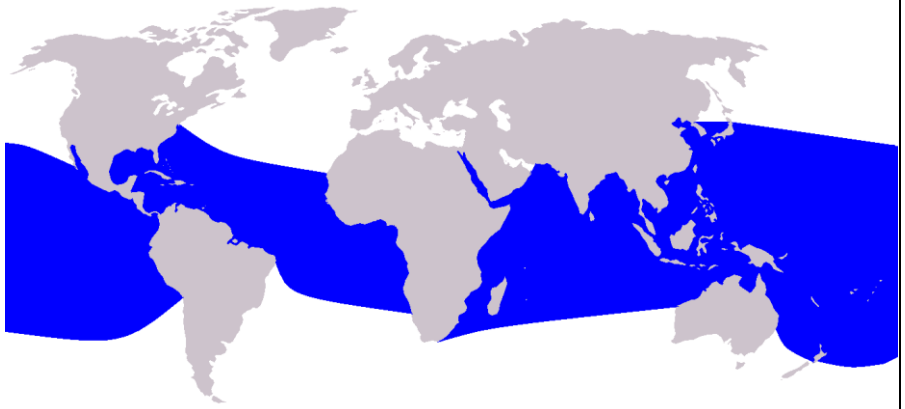
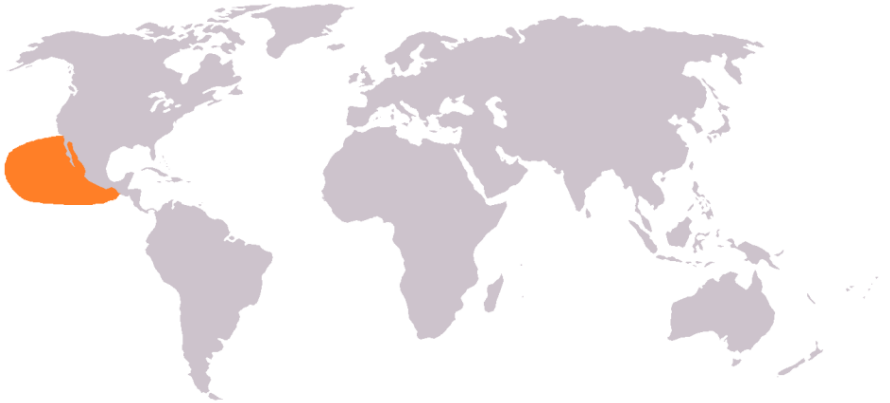
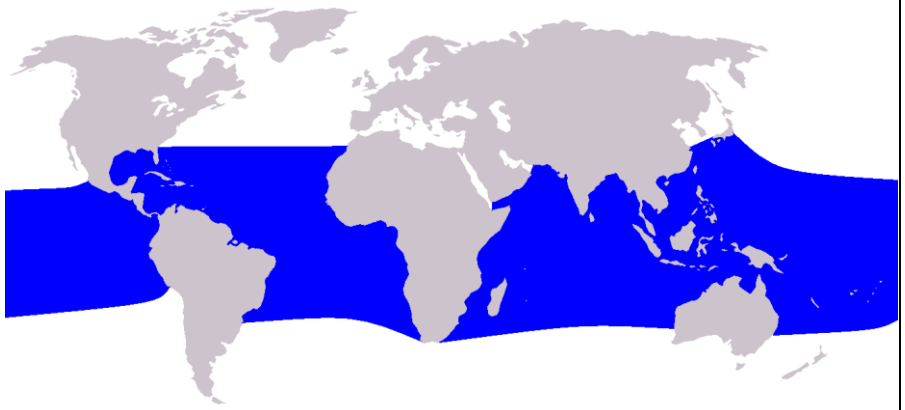
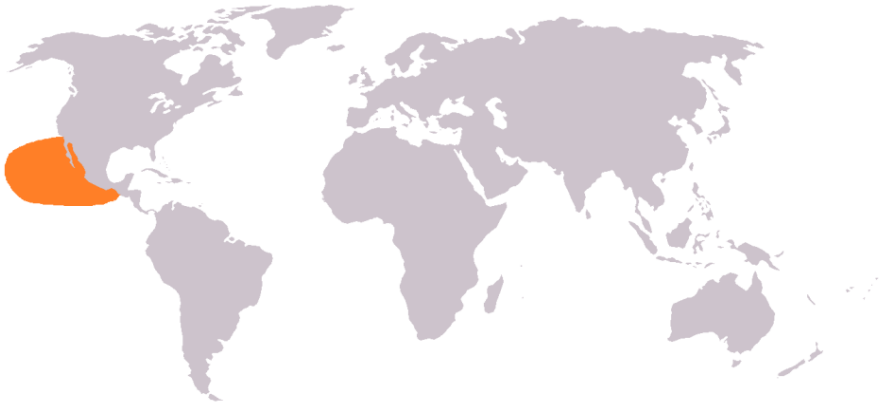
Table 18: Geographic location list of species abundance in the Pacific region section and the corresponding areas of examination of a given specie

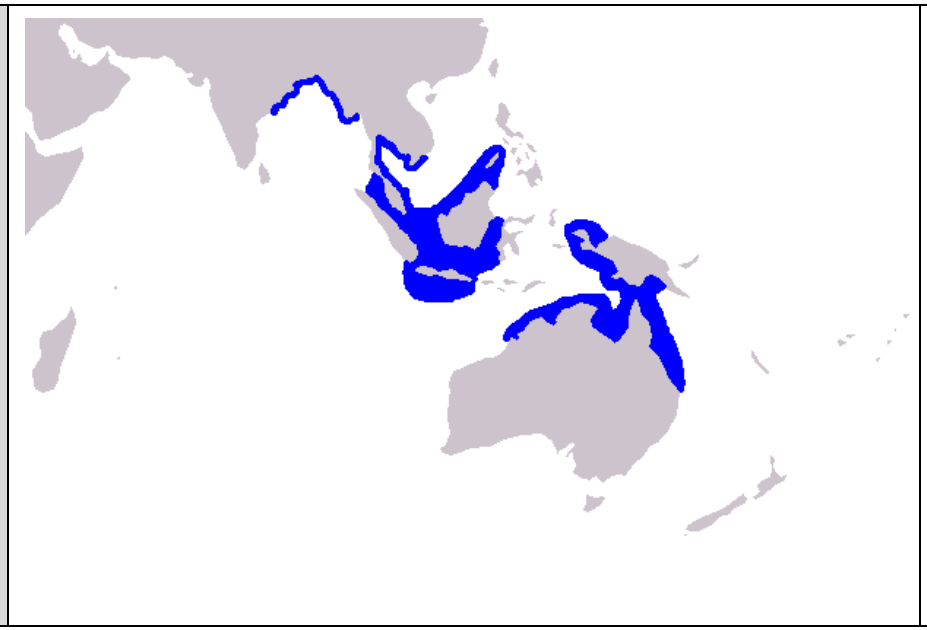
	Geographic location	Area of examination
Bottlenose dolphin		
Short-beaked common dolphin		

False killer whale		
Pantropical spotted dolphin		

Long-beaked common dolphin		
Short-finned pilot whale		

Rough-tooth dolphin		
Striped dolphin		

Spinner dolphin		
Pacific Fraser's dolphin		

Irrwaddy dolphin		

Appendix 2: Whistle parameter comparison graphs

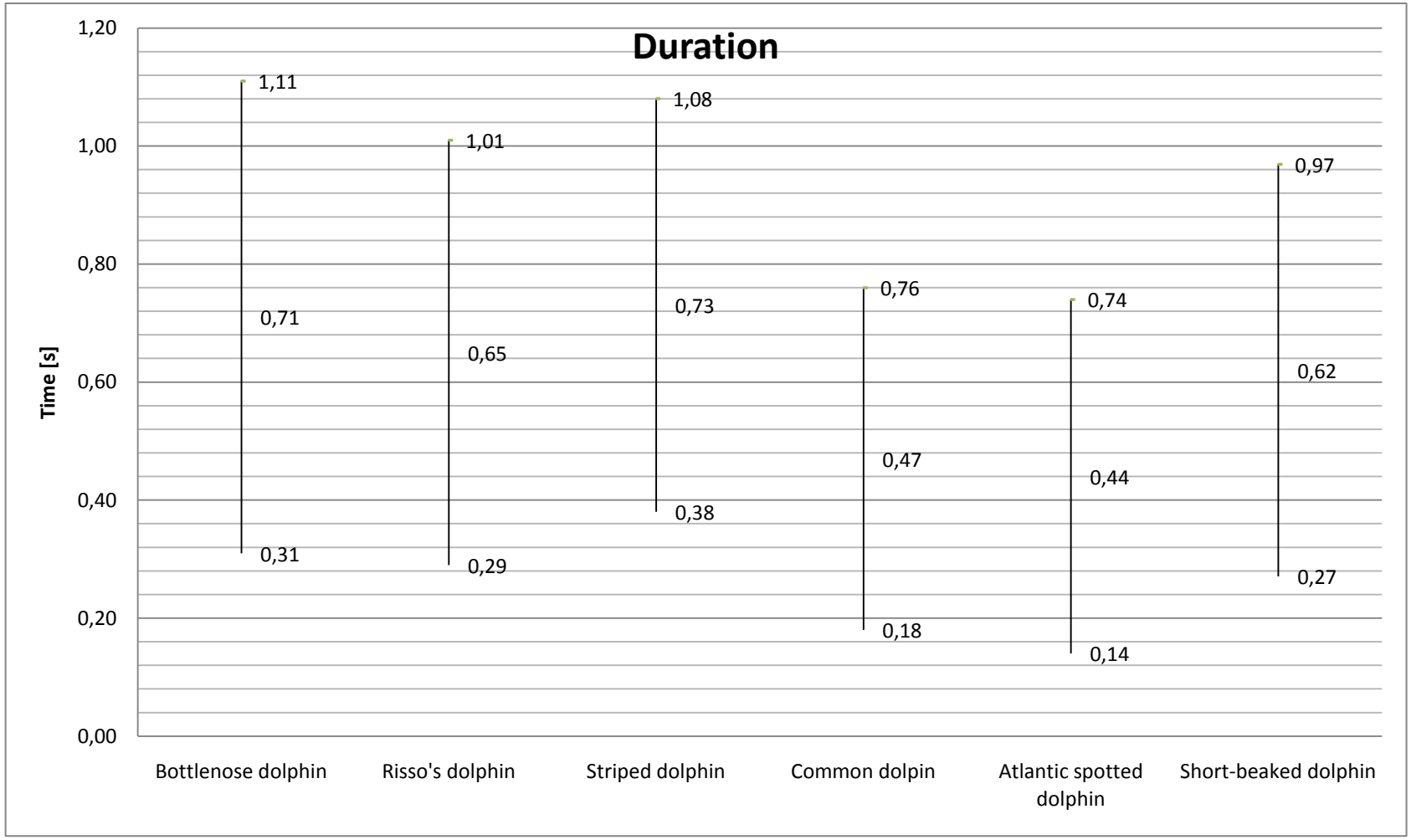


Fig. 76 Whistle duration values with their SD values considered for Atlantic region section

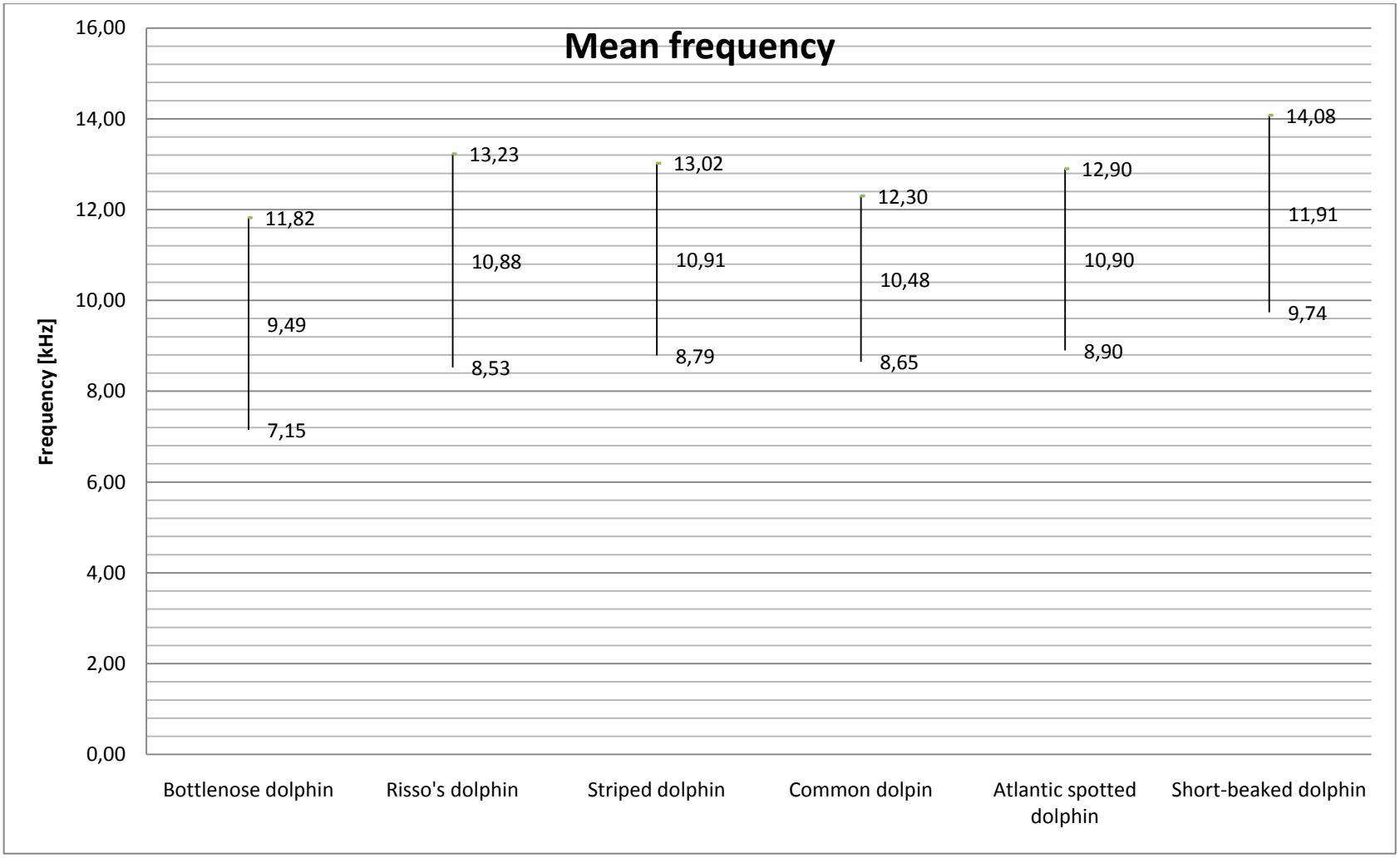


Fig. 77 Whistle mean frequency values with their SD values considered for Atlantic region section

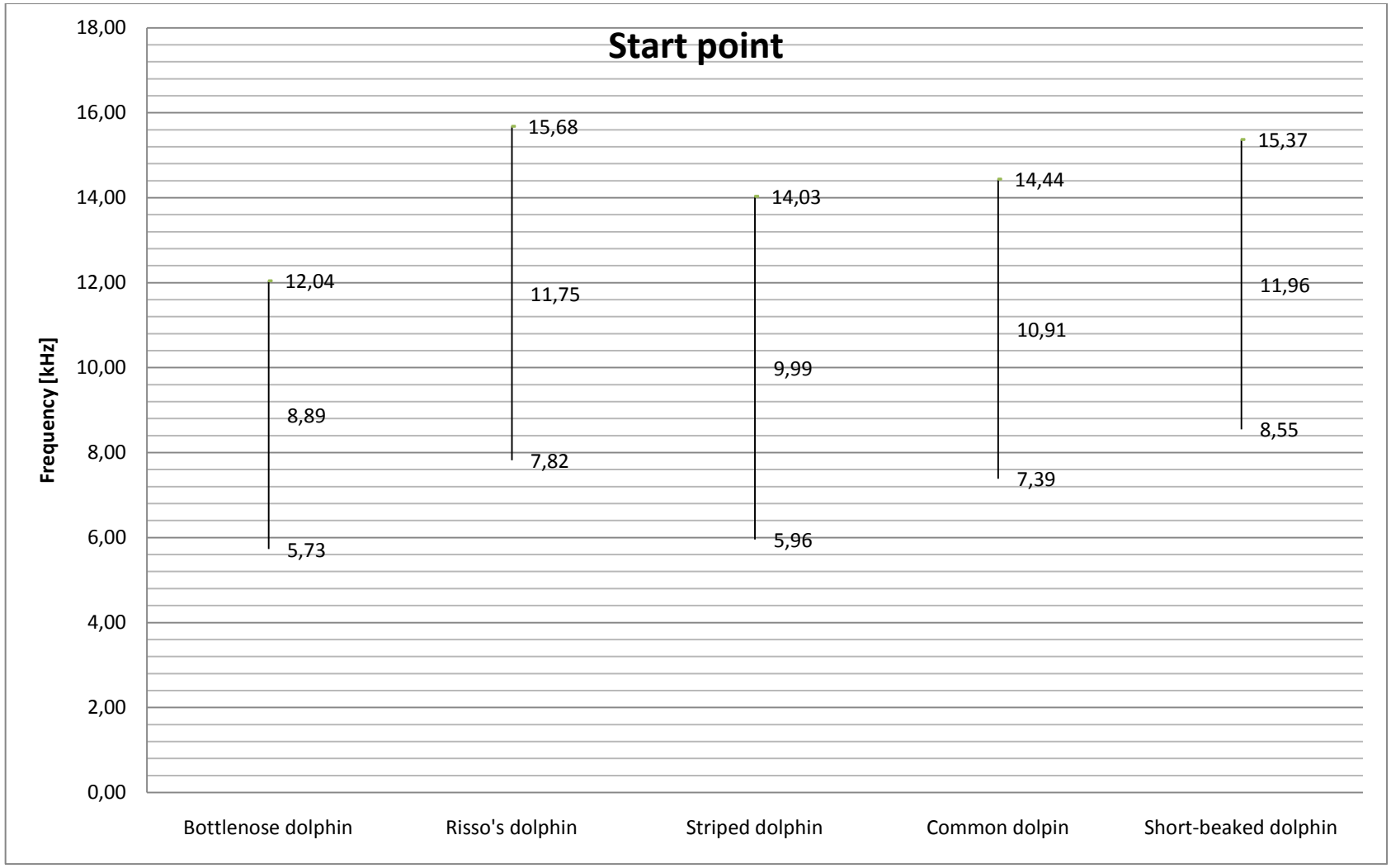


Fig. 78 Whistle start point values with their SD values considered for Atlantic region section

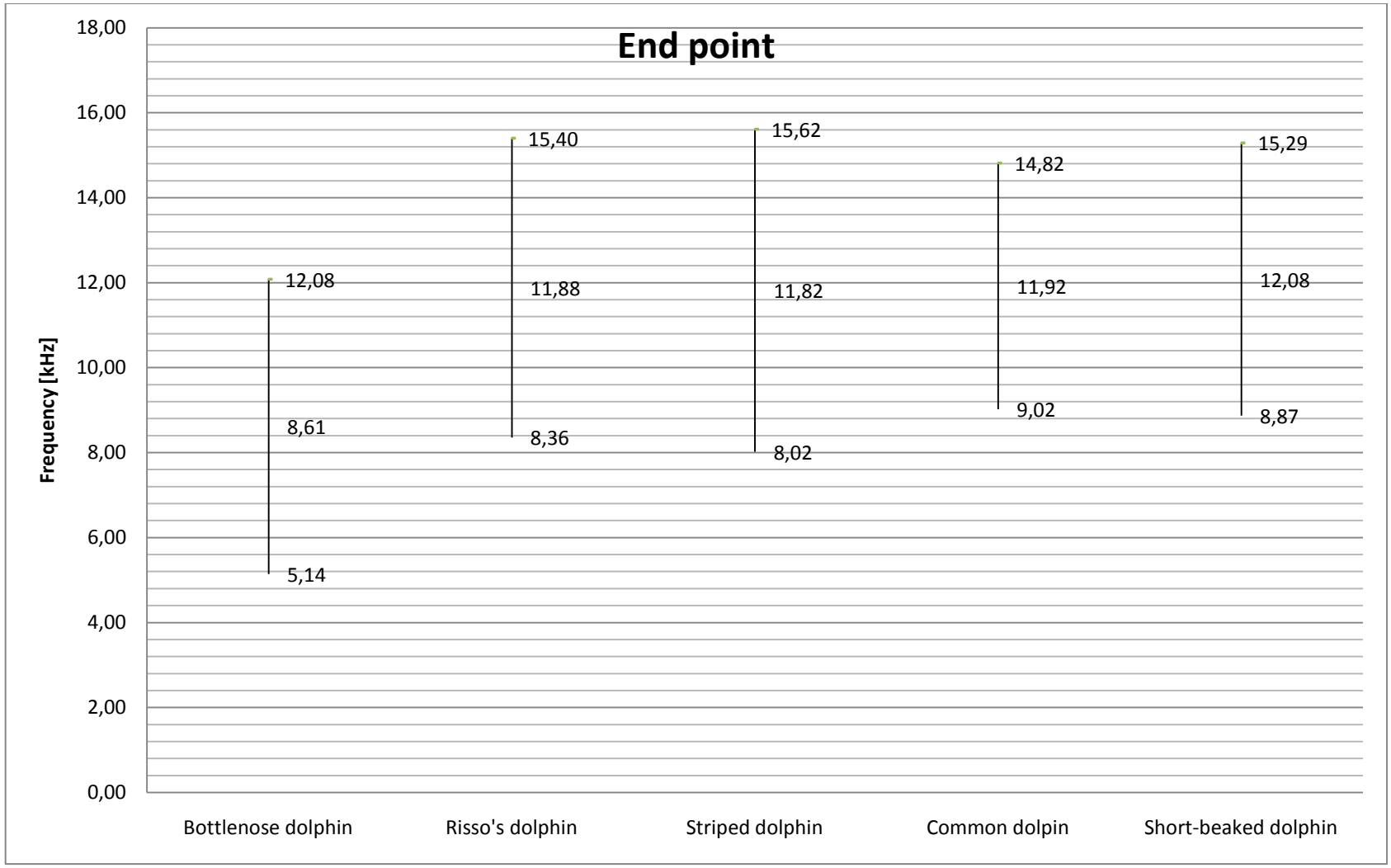


Fig. 79 Whistle end point values with their SD values considered for Atlantic region section

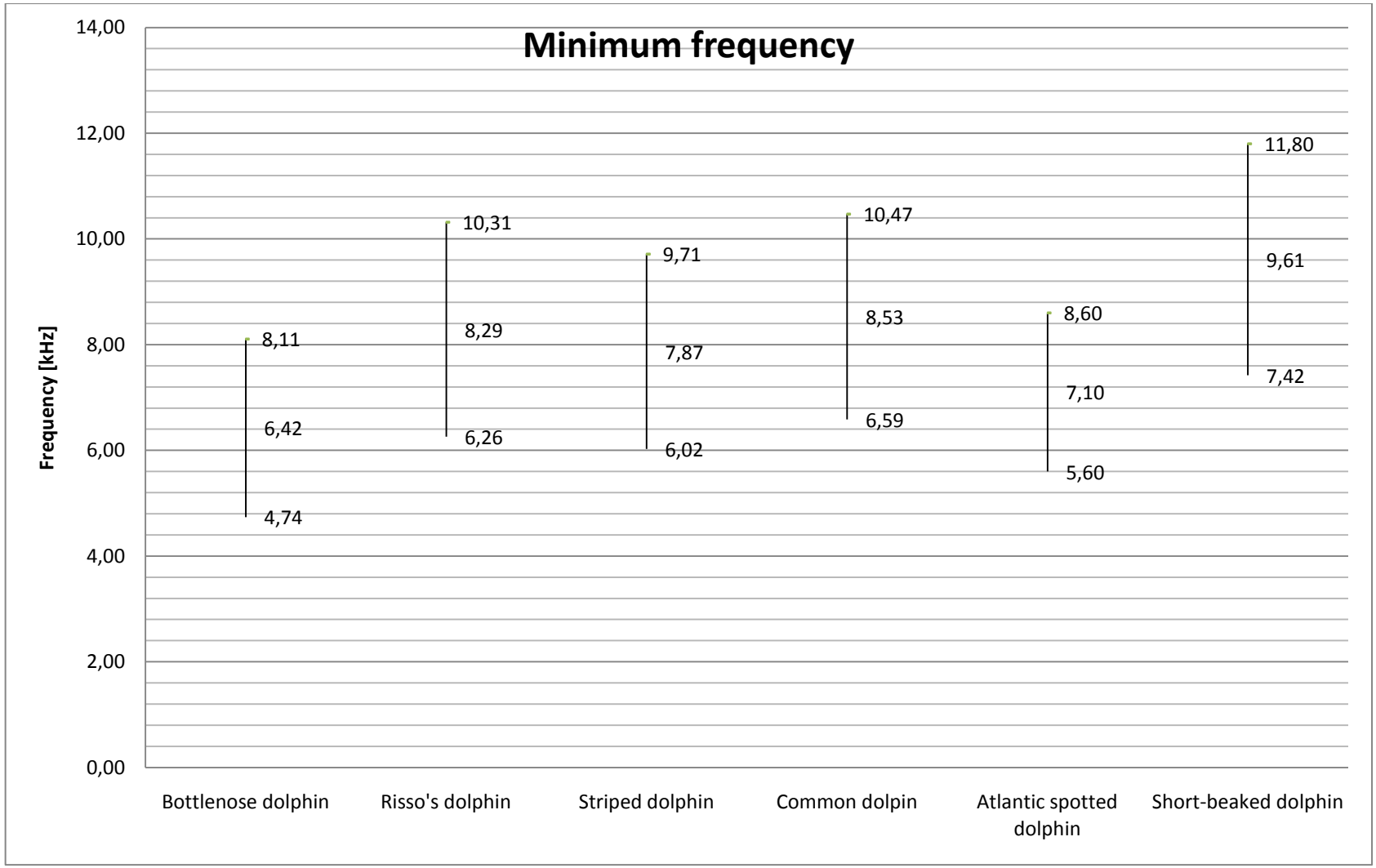


Fig. 80 Whistle minimum frequency values with their SD values considered for Atlantic region section

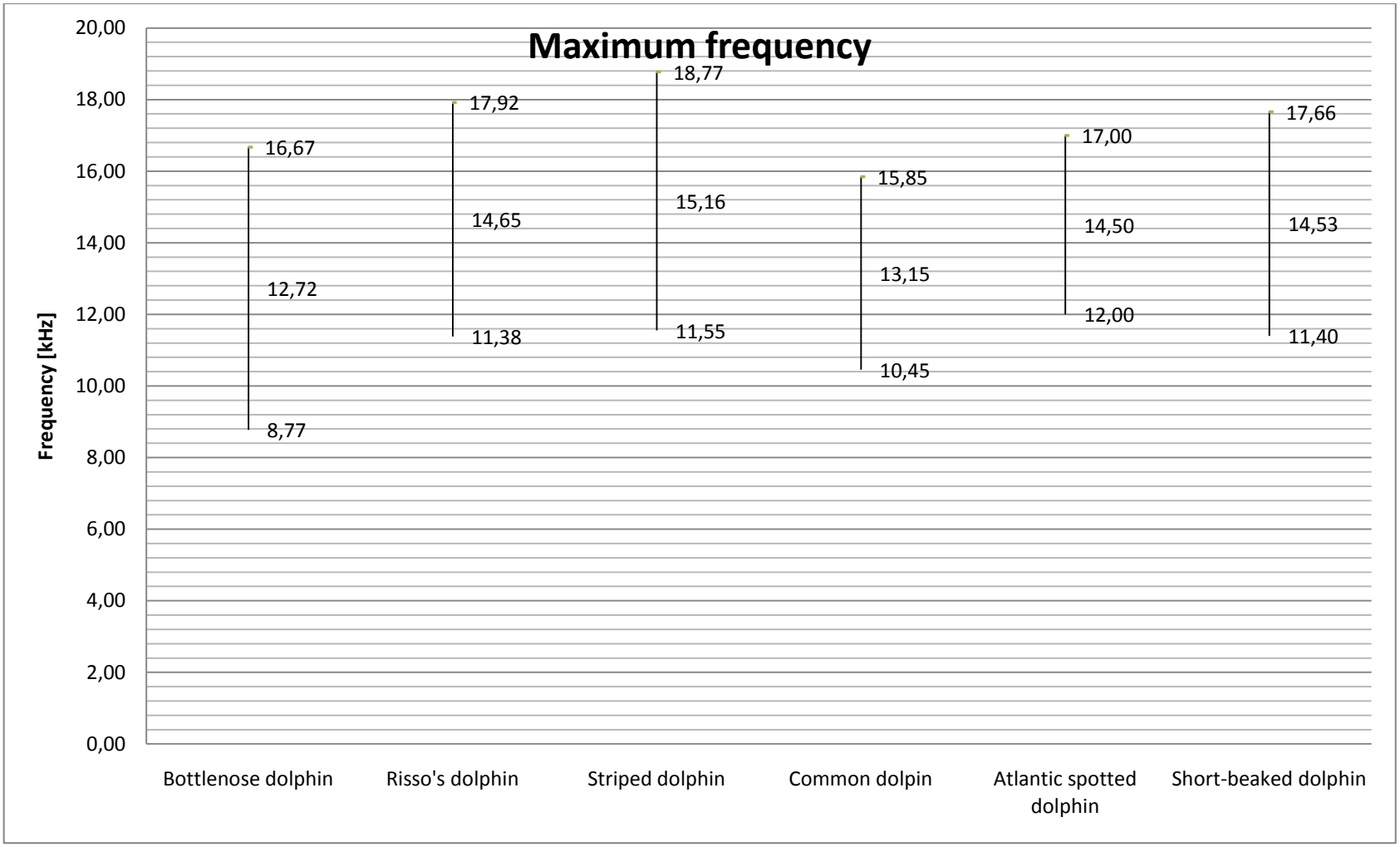
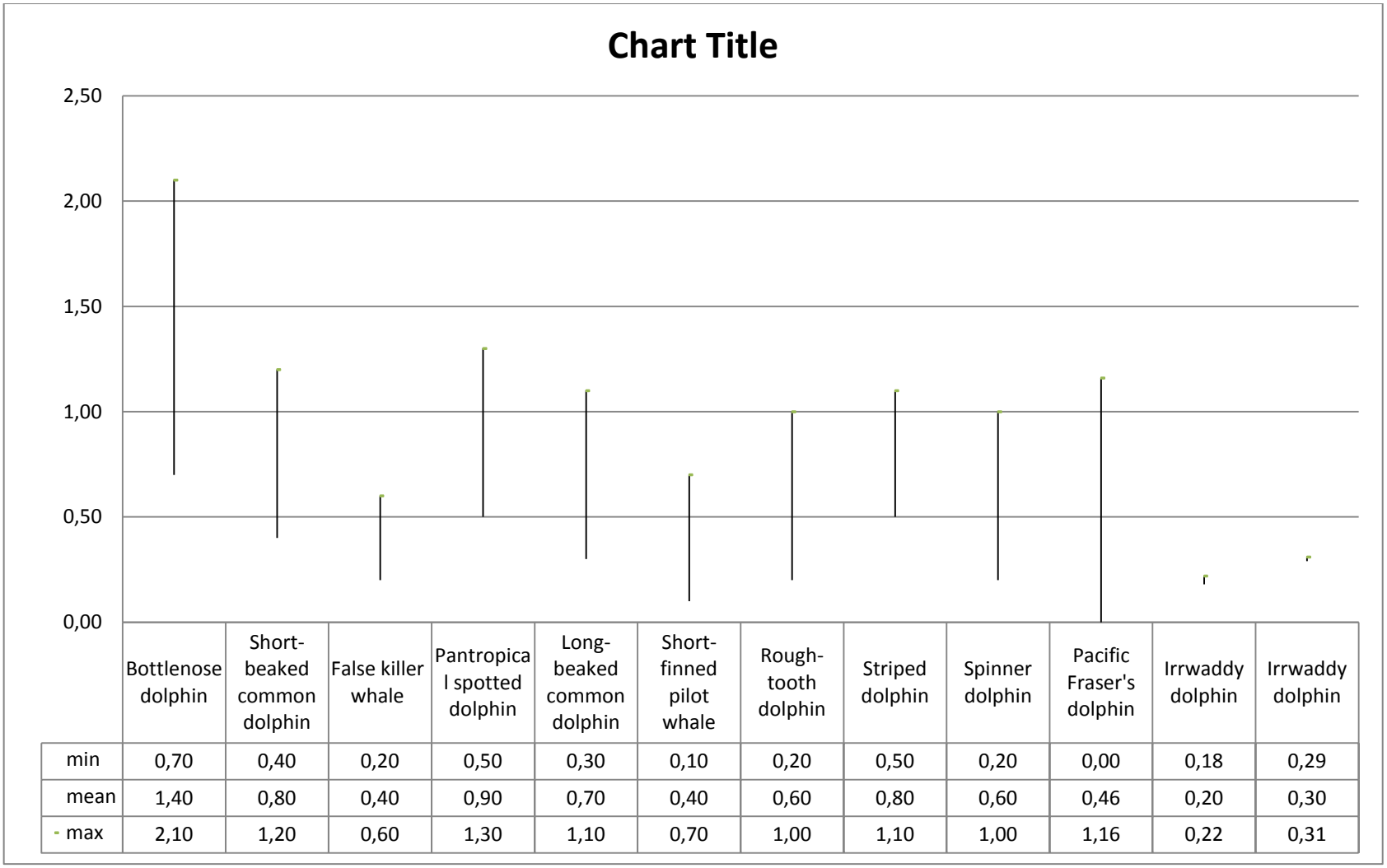


Fig. 81 Whistle maximum frequency values with their SD values considered for Atlantic region section



	Bottlenose dolphin	Short-beaked common dolphin	False killer whale	Pantropical spotted dolphin	Long-beaked common dolphin	Short-finned pilot whale	Rough-tooth dolphin	Striped dolphin	Spinner dolphin	Pacific Fraser's dolphin	Irrwaddy dolphin	Irrwaddy dolphin
min	0,70	0,40	0,20	0,50	0,30	0,10	0,20	0,50	0,20	0,00	0,18	0,29
mean	1,40	0,80	0,40	0,90	0,70	0,40	0,60	0,80	0,60	0,46	0,20	0,30
max	2,10	1,20	0,60	1,30	1,10	0,70	1,00	1,10	1,00	1,16	0,22	0,31

Fig. 82 Whistle duration values with their SD values considered for Pacific region section

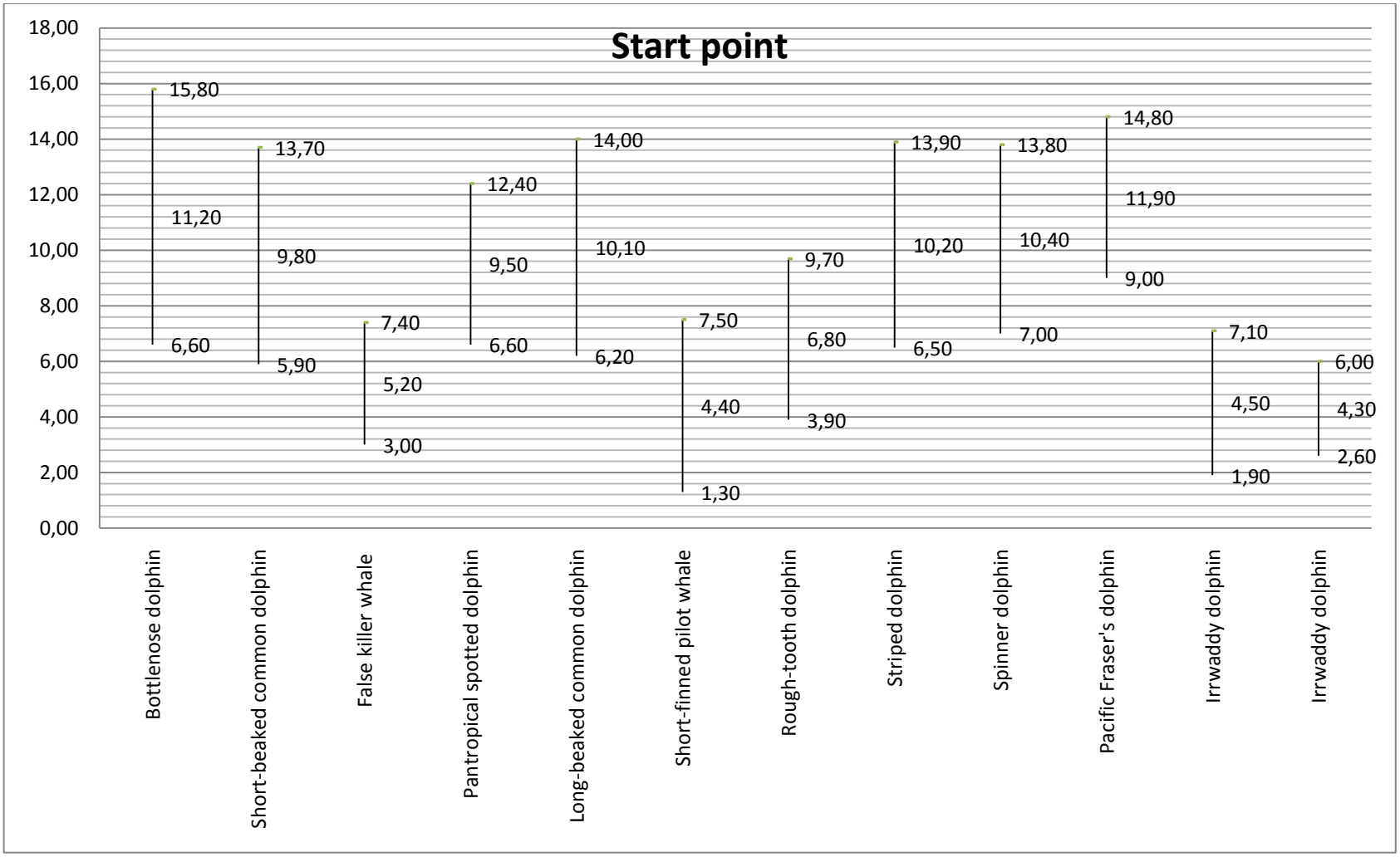


Fig. 83 Whistle start point values with their SD values considered for Pacific region section

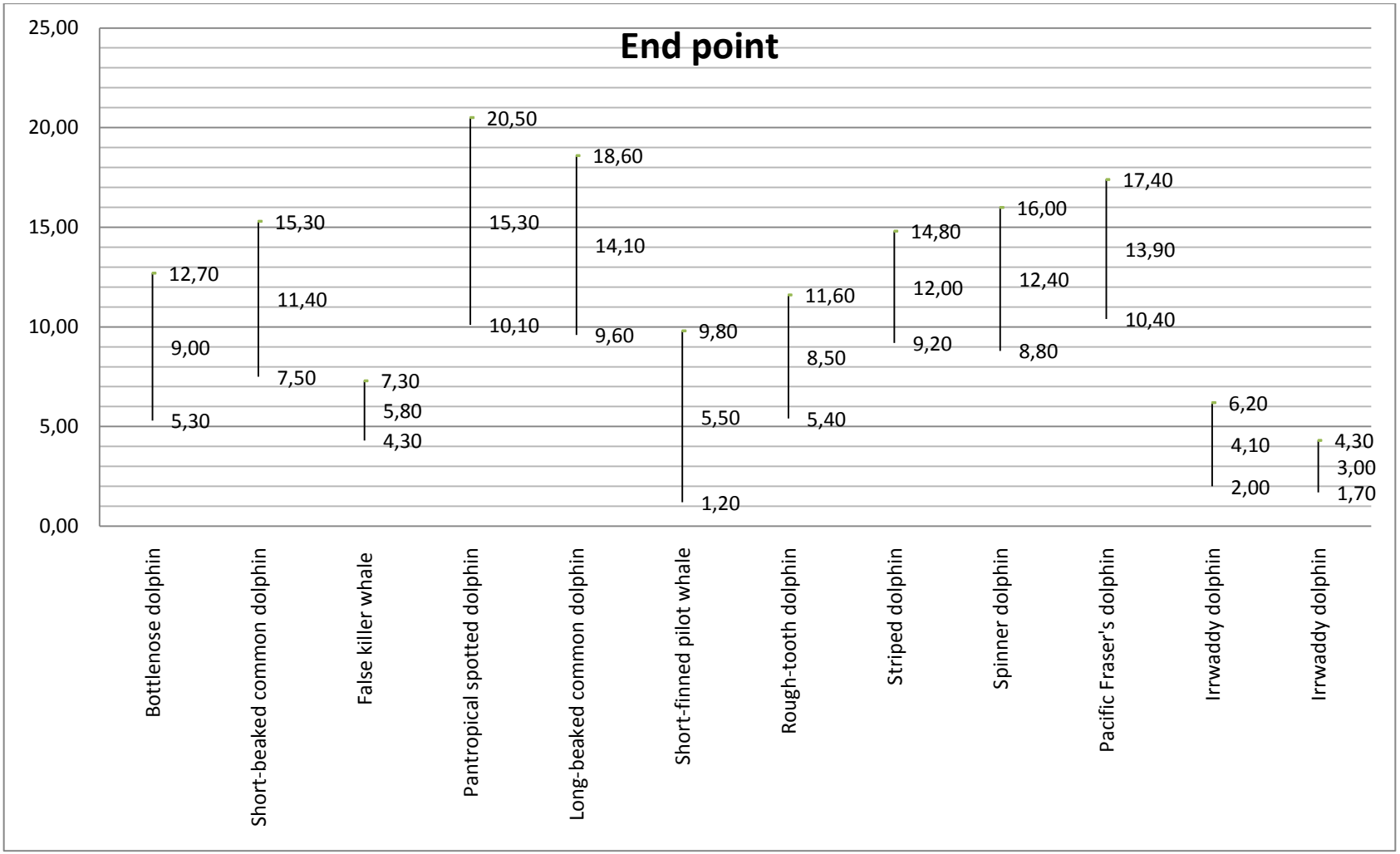


Fig. 84 Whistle end point values with their SD values considered for Pacific region section

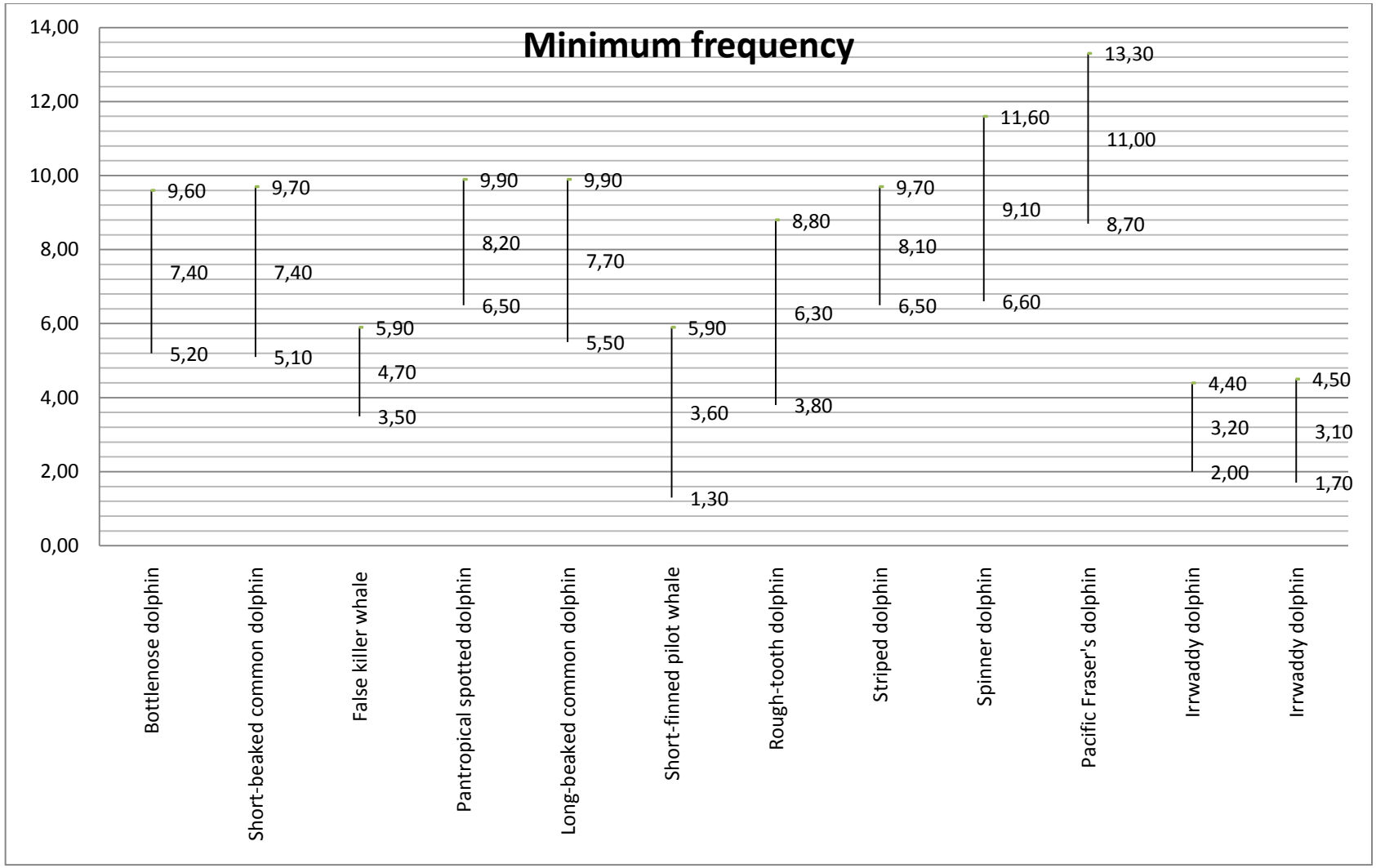
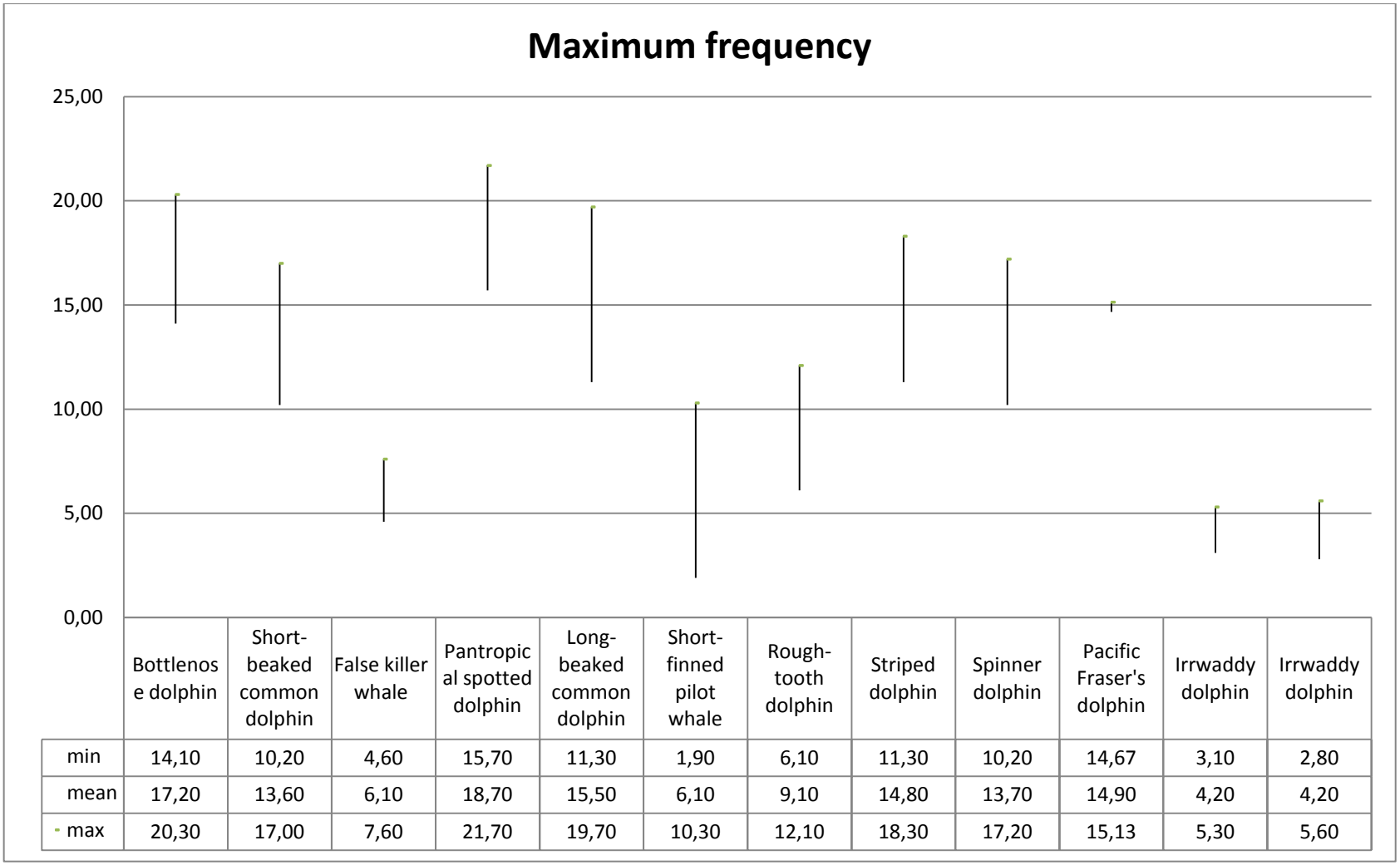


Fig. 85 Whistle minimum frequency values with their SD values considered for Pacific region section



	Bottlenose dolphin	Short-beaked common dolphin	False killer whale	Pantropical spotted dolphin	Long-beaked common dolphin	Short-finned pilot whale	Rough-tooth dolphin	Striped dolphin	Spinner dolphin	Pacific Fraser's dolphin	Irrwaddy dolphin	Irrwaddy dolphin
min	14,10	10,20	4,60	15,70	11,30	1,90	6,10	11,30	10,20	14,67	3,10	2,80
mean	17,20	13,60	6,10	18,70	15,50	6,10	9,10	14,80	13,70	14,90	4,20	4,20
max	20,30	17,00	7,60	21,70	19,70	10,30	12,10	18,30	17,20	15,13	5,30	5,60

Fig. 86 Whistle maximum frequency values with their SD values considered for Pacific region section

Appendix 3: Autodesk Algor Buoy data

Table 19 Autodesk Algor Buoy data

Model Information											
Volume (mm^3)	117850000	Weight (N)	1519.6								
Center of Gravity (mm)	Mass Moment of Intertia ($N*s^2*mm$)	Mass Product of Intertia ($N*s^2*mm$)									
Xc (mm)	250.52	Ixx ($N*s^2*mm$)	145750	Ixy ($N*s^2*mm$)							
Yc (mm)	315.72	Iyy ($N*s^2*mm$)	120290	Ixz ($N*s^2*mm$)							
Zc (mm)	451.19	Izz ($N*s^2*mm$)	74677	Iyz ($N*s^2*mm$)							
Part Information											
Part	Volume (mm^3)	Weight (N)	Xc (mm)	Yc (mm)		Ixx ($N*s^2*mm$)	Iyy ($N*s^2*mm$)	Izz ($N*s^2*mm$)	Ixy ($N*s^2*mm$)	Iyz ($N*s^2*mm$)	
1 < BOUY-FINAL: Counter weight >	5970400	76.98	252.06	-425.14		3389.1	2419.2	1993.8	-841.86	-1368.3	
2 < BOUY-FINAL: finalmast_Default >	1541400	19.87	242.34	1443.4		6136.1	2035.8	4451.8	708.36	2801.1	
3 < BOUY-FINAL: finalmast_Default >	7163900	92.37	248.43	1606.3		32659	7145.9	26783	3755.7	12522	
7 < BOUY-FINAL: boje2_Default >	13549000	174.69	258.42	228.06		2285.1	2750.7	3237.1	1049	-42.92	
8 < BOUY-FINAL: boje2_Default >	89628000	1155.6	249.53	255.77		101280	105940	38211	7533.5	16727	

Appendix 4: MES RIKS Analysis report

Analysis Autonomous accoustic buoy

Author: Andrea Johnson

Department: N/A

Created Date: 31/05/2010

Model Information

Analysis Type - MES Riks Analysis
Units - Custom - (N, mm, s, °C, K, V, ohm, A, J)
Model location - C:\Users\Andrea\Desktop\life stage 2.fem
Design scenario description - Design Scenario # 3

Analysis Parameters Information

Table 20: Multiphysics Information

Default Nodal Temperature	0 °C

Table 21 Processor Information

Event Duration	s
Capture Rate	1 /s
Analysis Type	Static Postbuckling and Collapse (RIKS)
Acceleration Due To Body Force	0 mm/s²
X Mutiplier	0
Y Mutiplier	0
Z Mutiplier	-1
Load Curve Number for Gravity Load	1
Type of Shell Pressure Loading	None

Load Curve Number for Shell Pressure Loads	
Smooth Shell Pressure	No
Hydrostatic Pressure Control for Shell Elements	None
Z Coordinate Datum for Hydrostatic Pressure	mm
Weight Density of Fluid Causing Shell Hydrostatic Pressure	N/mm³
Nodal Temperature Time-Variation Load Curve Index	1
Where On Disk Is Nodal Temperature Data Stored	No thermal Data
Temperature Data File	None
Output Results of All Time Steps	No
Output Results of All Time Steps With Wall Interaction	No
Calculate and Output Strains	No
Output Reaction Forces	Calculated
Number of time steps	1
Initial Time Step Size	1 s
Nonlinear Iterative Solution Method	Combined Newton
Maximum Number of Iterations	15
Convergence Criteria	Displacement
Displacement Tolerance	1e-4
Force Tolerance	1e-15

Line Search Convergence Tolerance	0.5
Number of Time Steps Between Iterations	1
Number of Time Steps Between Reforming Stiffness Matrix	1
Time Integration Methods Suggested for Type of Analysis	Static: NLS, LS
Parameter for MES Integration Method	
First Parameter for LS Integration Method	0.50
Second Parameter for LS Integration Method	0.25
Output interval	1
Starting Time for Event	0 s
Interval to save restart data.	Last step only.
Resume from Step	0
Resume/Extend Run	No
Time Step Number Extension	0
Use A Constant Time Step Size	No
Decrease Trigger: Rate of convergence	Unknown Value
Decrease Trigger: Allow for Non-monotonic convergence	Yes
Decrease Trigger: Compressed Elements	No
Decrease Trigger: High Solution Tolerance	Yes
Time Step Change Factor	2

Increase Trigger: Number of Convergent Time Steps	4
Increase Trigger: Increment to Number of Convergent Time Steps	4
Apply Rayleigh Damping	No
Mass-related Rayleigh Damping Coeeficient	0.05
Stiffness-related Rayleigh Damping Coefficient	0.05
Direction of Centrifugal Load Axis	Between Two Points
Centrifugal Load Curve Multiplier	1 mm/s²
Centrifugal Rotation	RPM
Load Curve Number for Centrifugal Load	1
X Coordinate of First Point of Axis	0 mm
Y Coordinate of First Point of Axis	0 mm
Z Coordinate of First Point of Axis	0 mm
X Coordinate of Second Point on Axis	0 mm
Y Coordinate of Second Point on Axis	0 mm
Z Coordinate of Second Point on Axis	0 mm
Time Step Data In Output File	No
Equation Numbers Data in Output File	No
Element Stiffness In Output File	No
Global Stiffness In Output File	No

Displacement of Nodes In Output File	No
Velocity of Nodes In Output File	No
Acceleration of Nodes In Output File	No
Element Input Data in Output File	No
Nodal Input Data in Output File	No
Initial Condition Input Data In Output File	No
Printout Blocks Output To File	No
Mass Representation	Lumped
Matrix Reform Interval Within Each Time Step	1
Maximum Stiffness Reformations Per Interval	1
Number of Time Steps Between Reforming Stiffness Matrix	1
Avoid Bandwidth Optimization	No
Bandwidth Optimization Method	Single Body
Convergence tolerance	1E-6
Maximum Number of Iterations	1000
Number of processors	All
Run Static Analysis	Yes

Table 22 Load curve information

Load Curve 1 Type	Time

Load Curve 1 Index 1 Time	0
Load Curve 1 Index 1 Multiplier	0
Load Curve 1 Index 2 Time	1
Load Curve 1 Index 2 Multiplier	1

Table 23 Part Information

Part ID	Part Name	Element Type	Material Name
1	BOUY-FINAL: Counter weight	Shell	Plastic- Polycarbonate (Molded)
2	BOUY-FINAL: finalmast_Default	Shell	Plastic- Polycarbonate (Molded)
3	BOUY-FINAL: finalmast_Default	Shell	Plastic- Polycarbonate (Molded)
7	BOUY-FINAL: boje2_Default	Shell	Plastic- Polycarbonate (Molded)
8	BOUY-FINAL: boje2_Default	Shell	Plastic- Polycarbonate (Molded)

Element Properties used for:

Table 24 BOUY-FINAL: Counter weight

Element Type	Shell
Shell type	General
Material Model	Isotropic
1st Integration Order	Unknown Value
2nd Integration Order	Unknown Value
Thickness	10.1438 mm
Midside Nodes	Not Included

Element Normal X Coordinate	mm
Element Normal Y Coordinate	mm
Element Normal Z Coordinate	mm
Allow for overlapping elements	No

Table 25 BOUY-FINAL: finalmast_Default

Element Type	Shell
Shell type	General
Material Model	Isotropic
1st Integration Order	Unknown Value
2nd Integration Order	Unknown Value
Thickness	9.9999 mm
Midside Nodes	Not Included
Element Normal X Coordinate	mm
Element Normal Y Coordinate	mm
Element Normal Z Coordinate	mm
Allow for overlapping elements	No

Table 26 BOUY-FINAL: finalmast_Default

Element Type	Shell
Shell type	General
Material Model	Isotropic

1st Integration Order	Unknown Value
2nd Integration Order	Unknown Value
Thickness	9.98655 mm
Midside Nodes	Not Included
Element Normal X Coordinate	mm
Element Normal Y Coordinate	mm
Element Normal Z Coordinate	mm
Allow for overlapping elements	No

Table 27 BOUY-FINAL: boje2_Default

Element Type	Shell
Shell type	General
Material Model	Isotropic
1st Integration Order	Unknown Value
2nd Integration Order	Unknown Value
Thickness	10 mm
Midside Nodes	Not Included
Element Normal X Coordinate	mm
Element Normal Y Coordinate	mm
Element Normal Z Coordinate	mm
Allow for overlapping elements	No

Table 28 BOUY-FINAL: boje2_Default

Element Type	Shell
Shell type	General
Material Model	Isotropic
1st Integration Order	Unknown Value
2nd Integration Order	Unknown Value
Thickness	10.347 mm
Midside Nodes	Not Included
Element Normal X Coordinate	mm
Element Normal Y Coordinate	mm
Element Normal Z Coordinate	mm
Allow for overlapping elements	No

Material Information

Table 29 Plastic- Polycarbonate (Molded) -Shell

Material Model	Standard
Material Source	Autodesk Algor Material Library
Material Source File	C:\Program Files\Autodesk\Algor Simulation 2011\matlibs\algormat.mlb
Date Last Updated	2004/09/30-16:00:00
Material Description	None

Mass Density	1.31374002450777e-009 N·s²/mm/mm³
Modulus of Elasticity	2378.69126600378 N/mm²
Poisson's Ratio	.37
Shear Modulus of Elasticity	785.230118558373 N/mm²

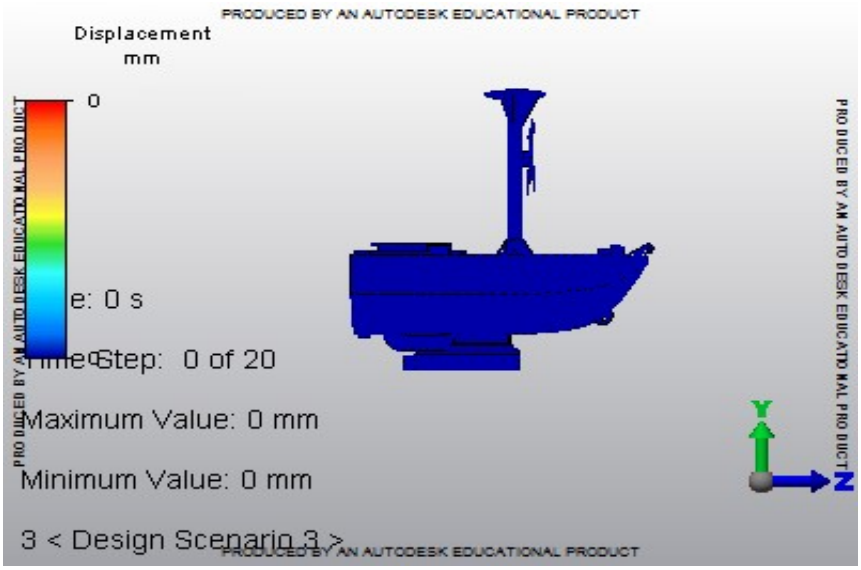


Fig. 87 Results Presentation Images

** Input initial conditions

Initial conditions code . . . . . (ICON) = 0
EQ.0: Zero initial conditions
EQ.1: Initial conditions are read
EQ.2: Initial conditions are read from .PIN file
EQ.3: Initial conditions are read from .INI file
(but MODEX.eq.2 over-rides ICON)

** Element Part Data
Element part number (Nonlinear) . . . . . = 1
3-D Shell Element Definition (Type 26)
Number of elements . . . . . .NPAR(2). . . = 2717
Analysis Type . . . . . .NPAR(3). . . = 2
eq.1, Linear or Material Nonlinearity Only
eq.2, Total Lagrangian Formulation
eq.3, Updated Lagrangian Formulation
Max number of nodes for a element . . . .NPAR(7). . . = 4

Integration Order for Element Stiffness Matrice
R direction . . . . . = 2
S direction . . . . . = 2
T direction . . . . . = 2
Number of Stress Output Tables . . . . .NPAR(13) . . = 0
eq.0, Output at Integration Points
Number of Thickness Tables . . . . . .NPAR(14) . . = 1
Material Model. . . . . .NPAR(15) . . = 1
eq.1, Linear Elastic Isotropic
eq.2, Linear Elastic Orthotropic
eq.3, Elasto-Plastic with Isotropic Hardening
eq.4, Elasto-Plastic with Kinematic Hardening
eq.5, Elasto-plastic with Multlinear IsotropicHardening
eq.6, Elasto-plastic with Multilinear KinematicHardening
eq.8, Mooney-Rivlin
eq.9, Ogden
eq.105, Viscoelastic Mooney-Rivlin
eq.106, Viscoelastic Ogden
Number of Different Sets of Material . .NPAR(16) . . = 1
Number of Material Constants per Set . .NPAR(17) . . = 0

Nodal Rotation Coordinate Guidance Vector:

Number	Direction Cosines		
1	1.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000

Material Properties Group No. 1

Mass Density . . . . . = 1.3137E-09
Young's Modulus (E) . . . . . = 2.3787E+03
Poisson's Ratio (Nu). . . . . = 3.7000E-01
Shear Shape Factor (Fs) . . . . = 1.2000E+00
Shear Modulus (G) . . . . . = 7.8523E+02

Element Thickness Data

Node01 Node02 Node03 Node04

Set 1
1.000E+01 1.000E+01 1.000E+01 1.000E+01

** 3-D Shell element data suppressed (use /PRELE to print)

Element part number (Nonlinear) . . . . . = 3

3-D Shell Element Definition (Type 26)
Number of elements . . . . . .NPAR(2). . . = 4126
Analysis Type . . . . . .NPAR(3). . . = 2
eq.1, Linear or Material Nonlinearity Only
eq.2, Total Lagrangian Formulation
eq.3, Updated Lagrangian Formulation
Max number of nodes for a element . . . .NPAR(7). . . = 4
Integration Order for Element Stiffness Matrice
R direction . . . . . = 2
S direction . . . . . = 2
T direction . . . . . = 2
Number of Stress Output Tables . . . . .NPAR(13) . . = 0
eq.0, Output at Integration Points
Number of Thickness Tables . . . . . .NPAR(14) . . = 1
Material Model. . . . . .NPAR(15) . . = 1
eq.1, Linear Elastic Isotropic
eq.2, Linear Elastic Orthotropic
eq.3, Elasto-Plastic with Isotropic Hardening
eq.4, Elasto-Plastic with Kinematic Hardening
eq.5, Elasto-plastic with Multlinear IsotropicHardening
eq.6, Elasto-plastic with Multilinear KinematicHardening
eq.8, Mooney-Rivlin
eq.9, Ogden
eq.105, Viscoelastic Mooney-Rivlin
eq.106, Viscoelastic Ogden
Number of Different Sets of Material . .NPAR(16) . . = 1
Number of Material Constants per Set . .NPAR(17) . . = 0

Nodal Rotation Coordinate Guidance Vector:

Number	Direction Cosines		
1	1.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000

Material Properties Group No. 1

Mass Density . . . . . = 1.3137E-09
Young's Modulus (E) . . . . . = 2.3787E+03
Poisson's Ratio (Nu). . . . . = 3.7000E-01
Shear Shape Factor (Fs) . . . . = 1.2000E+00
Shear Modulus (G) . . . . . = 7.8523E+02

Element Thickness Data

Node01 Node02 Node03 Node04

Set 1
9.987E+00 9.987E+00 9.987E+00 9.987E+00

** 3-D Shell element data suppressed (use /PRELE to print)

Element part number (Nonlinear) . . . . . = 7

3-D Shell Element Definition (Type 26)
Number of elements . . . . . .NPAR(2). . . = 6534
Analysis Type . . . . . .NPAR(3). . . = 2
eq.1, Linear or Material Nonlinearity Only
eq.2, Total Lagrangian Formulation
eq.3, Updated Lagrangian Formulation
Max number of nodes for a element . . . .NPAR(7). . . = 4
Integration Order for Element Stiffness Matrice
R direction . . . . . = 2
S direction . . . . . = 2
T direction . . . . . = 2
Number of Stress Output Tables . . . . .NPAR(13) . . = 0
eq.0, Output at Integration Points
Number of Thickness Tables . . . . . .NPAR(14) . . = 1
Material Model. . . . . .NPAR(15) . . = 1
eq.1, Linear Elastic Isotropic
eq.2, Linear Elastic Orthotropic
eq.3, Elasto-Plastic with Isotropic Hardening
eq.4, Elasto-Plastic with Kinematic Hardening
eq.5, Elasto-plastic with Multlinear IsotropicHardening
eq.6, Elasto-plastic with Multilinear KinematicHardening
eq.8, Mooney-Rivlin
eq.9, Ogden
eq.105, Viscoelastic Mooney-Rivlin
eq.106, Viscoelastic Ogden
Number of Different Sets of Material . .NPAR(16) . . = 1
Number of Material Constants per Set . .NPAR(17) . . = 0

Nodal Rotation Coordinate Guidance Vector:

Number	Direction Cosines		
1	1.0000	0.0000	0.0000
2	0.0000	1.0000	0.0000

Material Properties Group No. 1

Mass Density . . . . . = 1.3137E-09
Young's Modulus (E) . . . . . = 2.3787E+03

```
   Poisson's Ratio  (Nu). . . . . =  3.7000E-01
   Shear Shape Factor (Fs) . . . . =  1.2000E+00
   Shear Modulus (G) . . . . . . . =  7.8523E+02

  Element Thickness Data

  Node01    Node02    Node03    Node04

Set     1
1.035E+01 1.035E+01 1.035E+01 1.035E+01

** 3-D Shell element data suppressed (use /PRELE to print)
** Maximum hits per equation (EQN:85801) = 403
  Nonzero entries estimated in upper triangle matrix = 15924204
** BCSLIB-EXT Sparse Solver for Models with Actuator/Pulley/Slider:

** Solution State Parameters (2)
** mTOT,maxSizeA,mUSE,mFRE(8 Bytes)
== 0, 2047418, 0, 0
** mGK(%) (doubles)
== 14563683 (2% of Physical Memory)
** iSPARSE,iPACK,iCHOP,kLIN,iSTAT,iMASS
== 5,0,0,1,0,0
** maxK,kLEVEL,nrestart,kSTEP,kEXIT,iRUN
== 1,1,0,0,0,0
** n_step,n_case,nste_ext,totalT,dt0
== 0,0,0,   1.200000000000000E+02,   1.000000000000000E+00

** Initial condition list (in node#) suppressed (use /PRINI to print)
** Time integration information suppressed (use /PRTIME to print)
    BCSLIB-EXT solver memory status:
    in-core memory requirement (MB) =         965.75
    minimum memory requirement (MB) =         154.74
        user specified memory (MB) =        1046.17
     available physical memory (MB) =        1046.17
      available virtual memory (MB) =        4699.20
    memory currently allocated (MB) =         965.75

** Input model name      : C:\Users\Andrea\Desktop\life stage 2.ds_data\3\ds
** Free/total disk space :  293883.23 MB /  464475.02 MB
** Job started           : 2010-05-31  16:51:19
** Job finished          : 2010-05-31  18:21:49
** Total elapsed time    : 1:30:30 (hours:minutes:seconds)
```

Appendix 5: Interrupt control registers

Table 30 INTCON: INTERRUPT CONTROL REGISTER

R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W -xq
GIE/GIEH	PEIE/GIEL	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF
Bit7							Bit 0

Table 31 INTCON2: INTERRUPT CONTROL REGISTER 2

R/W - 1	R/W - 1	R/W - 1	R/W - 1	U - 0	R/W - 1	U - 0	R/W - 1
~RBPU	INTEDG0	INTEDG1	INTEDG2	-	TMR0IP	-	RBIP
Bit7							Bit 0

Appendix 6: SPI control registers

Table 32 SSPSTAT: MSSP STATUS REGISTER (SPI MODE)

R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0
WCOL	SSPOV	SSPEN	CKP	SSPM3	SSPM2	SSPM1	SSPM0
Bit7							Bit 0

Table 33 SSPCON1: MSSP CONTROL REGISTER 1

R/W - 0	R/W - 0	R-0	R-0	R-0	R-0	R-0	R-0
SMP	CKE	D/~A	P	S	R/~W	UA	BF
Bit7							Bit 0

Appendix 7: USART control registers

Table 34 TXSTA: TRANSMT STATUS AND CONTROL REGISTER

R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W – 0	R - 1	R/W - 0
CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D
Bit7							Bit 0

Table 35RCSTA: RECEIVE STATUS AND CONTROL REGISTER

R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W – 0	R - 0	R- 0	R/W - x
SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D
Bit7							Bit 0

Appendix 8: A/D control registers

Table 36 PCFG3:PCFG0: A/D PORT CONFIGURATION CONTROL BITS

PCFG3: PCFG0	AN12	AN11	AN10	AN9	AN8	AN7	AN6	AN5	AN4	AN3	AN2	AN1	AN0
0000	A	A	A	A	A	A	A	A	A	A	A	A	A
0001	A	A	A	A	A	A	A	A	A	A	A	A	A
0010	A	A	A	A	A	A	A	A	A	A	A	A	A
0011	D	A	A	A	A	A	A	A	A	A	A	A	A
0100	D	D	A	A	A	A	A	A	A	A	A	A	A
0101	D	D	D	A	A	A	A	A	A	A	A	A	A
0110	D	D	D	D	A	A	A	A	A	A	A	A	A
0111	D	D	D	D	D	A	A	A	A	A	A	A	A
1000	D	D	D	D	D	D	A	A	A	A	A	A	A
1001	D	D	D	D	D	D	D	A	A	A	A	A	A
1010	D	D	D	D	D	D	D	D	A	A	A	A	A
1011	D	D	D	D	D	D	D	D	D	A	A	A	A
1100	D	D	D	D	D	D	D	D	D	D	A	A	A
1101	D	D	D	D	D	D	D	D	D	D	D	A	A
1110	D	D	D	D	D	D	D	D	D	D	D	D	A
1111	D	D	D	D	D	D	D	D	D	D	D	D	D

Table 37 ADCON0:A/D CONTROL REGISTER 0

U - 0	U - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0
-	-	CHS3	CHS2	CHS1	CHS0	GO/~DONE	ADON
Bit7							Bit 0

Table 38 ADCON1: A/D CONTROL REGISTER 1

U - 0	U - 0	R/W - 0	R/W - 0	R/W - 0	R/W - q	R/W - q	R/W - q
-	-	VCFG1	VCFG0	PCFG3	PCFG2	PCFG1	PCFG0
Bit7							Bit 0

Table 39 ADCON2:A/D CONTROL REGISTER 2

R/W - 0	U - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0	R/W - 0
ADFM	-	ACQT2	ACQT1	ACQT0	ADCS2	ADCS1	ADCS0
Bit7							Bit 0

Legend:		
R = Readable bit	W = Writable bit	U = Unimplemented bt, read as , ’0’
- n = Value at POR	’1’ = Bit is set	’0’ = Bit is cleared x= Bit is unknown

Appendix 9: List of commands and status register description of the SHT73

Table 40 SHT73: list of commands

Comand	Code
Reserved	0000x
Measure Temperature	00011
Measure Relative Humidity	00101
Read Status Register	00111
Write Status Register	00110
Reserved	0101x – 1110x
Soft reset, reset the interface, clears the status register to default values. Wait minimum 11ms before next command	11110

Table 41 SHT73 Status register bits

Bit	Type	Description	Default	
7		Reserved	0	
6	R	End of battery (low voltage detection) ’0’ for VDD > 2.47V ’1’ for VDD < 2.47V	X	No default value, bit is only updated after a measurement
5		Reserved	0	
4		Reserved	0	
3		For testing onlu, do not use	0	
2	R/W	Heater	0	off
1	R/W	No reload from OTP	0	reload
0	R/W	’1’ = 8bitRH/12bit Temp. Resolution ’0’ = 12bit RH/ 14bit Temp. resolution	`0	12 bit RH 14 bit Temp.

Appendix 10: Conversion coefficients used in humidity and temperature computation formulas

Table 42 Temperature conversion coefficents

VDD	d1(C)	d1(F)
5V	-40.1	-40.2
4V	-39.8	-39.6
3.5V	-39.7	-39.5
3V	-39.6	-39.3
2.5V	-39.4	-38.9

SO_T	d2(◦C)	d2(◦F)
14bit	0.01	0.018
12bit	0.04	0.072

Table 43 Optimized humidity conversion coefficients

SO_{RH}	c_1	c_2	c_3
12bit	-2.0468	0.0367	-1.5955E-6
8bit	-2.0468	0.5872	-4.0845E-4

Table 44 Temperature compensation coefficients

SO_{RH}	t_1	t_2
12bit	0.01	0.00008
8bit	0.01	0.00128

Appendix 11: Accelerometer control registers and timing requirements

Table 45 SPI – serial peripheral interface timing

Symbol	Parameter	Value		Unit
		Min	Max	
tc(SPC)	SPI clock cycle	125		Ns
fc(SPC)	SPI clock frequency		8	MHz
tsu(CS)	CS setup time	5		ns
th(CS)	CS hold time	10		
tsu(SI)	SDI input setup time	5		
th(SI)	SDI input hold time	15		
tv(SO)	SDO valid output time		55	
th(SO)	SDO output hold time	7		
tdis(SO)	SDO output disable time		50	

Table 46 Accelermeter control register number 1: CTRL_REG1(20h)

PD1	PD0	DF1	DF0	ST	Zen	Yen	Xen

PD1, PD0	Power Down Control (00: power down mode; 01,10,11: device on)
DF1, DF0	Decmation Factor Control

	(00: decimate by 512; 01: decimate by 128; 10: decimate by 32; 11: decimate by 8)
ST	Self Test Enable (0: normal mode; 1: self-test active)
Zen	Z – acis enable (0: axis off; 1: axis on)
Yen	Y – acis enable (0: axis off; 1: axis on)
Xen	X – acis enable (0: axis off; 1: axis on)

Table 47Accelerometer control register number 2: CTRL_REG2(21h)

FS	BDU	BLE	BOOT	IEN	DRDY	SIM	DAS

FS	Full Scale selection (0: ± 2g; 1: ±6g)
BDU	Block Data Update (0: continuous update; 1:output registers not updated between MSB and LSB reading)
BLE	Big/Little Endian selection (0: little endian; 1: big endian)
BOOT	Reboot memory content
IEN	Interrupt Enable (0: data ready on RDY pad; 1: Interrupt events on RDY pad)
DRDY	Enable Data-Ready generation
SIM	SPI Serial Interface Mode selecton (0: 4-wire interface; 1: 3-wire interface)
DAS	Data Alignament Selection (0: 12 bit right justified; 1: 16 bit left justified)

Table 48 Status Register : STATUS_REG (27h)

ZYXOR	ZOR	YOR	XOR	ZYXDA	ZDA	YDA	XDA

ZYXOR	X, Y, and Z ais Data Overrun
ZOR	Z axis Data Overrun
YOR	Z axis Data Overrun
XOR	Z axis Data Overrun
ZYXDA	X, Y and Z axis new Data Available
ZDA	Z axis new Data Available
YDA	Y axis new Data Available
XDA	X axis new Data Available

Table 49 OUTX_L (28h) - x axis acceleration LSB

XD7	XD6	XD5	XD4	XD3	XD2	XD1	XD0

Table 50 OUTX_H (29h) - x axis acceleration MSB

XD15	XD14	XD13	XD12	XD11	XD10	XD9	XD8

Table 51 OUTY_L (2Ah) - y axis acceleration LSB

YD7	YD6	YD5	YD4	YD3	YD2	YD1	YD0

Table 52 OUTY_H (2Bh) - y axis acceleration MSB

YD15	YD14	YD13	YD12	YD11	YD10	YD9	YD8

Table 53 OUTZ_L (2Ch) - z axis acceleration LSB

Z7	Z6	Z5	Z4	Z3	Z2	Z1	Z0

Table 54 OUTZ_H (2Dh) - z axis acceleration MSB

Z15	Z14	Z13	Z12	Z11	Z10	Z9	Z8

Appendix 12: Software block diagram

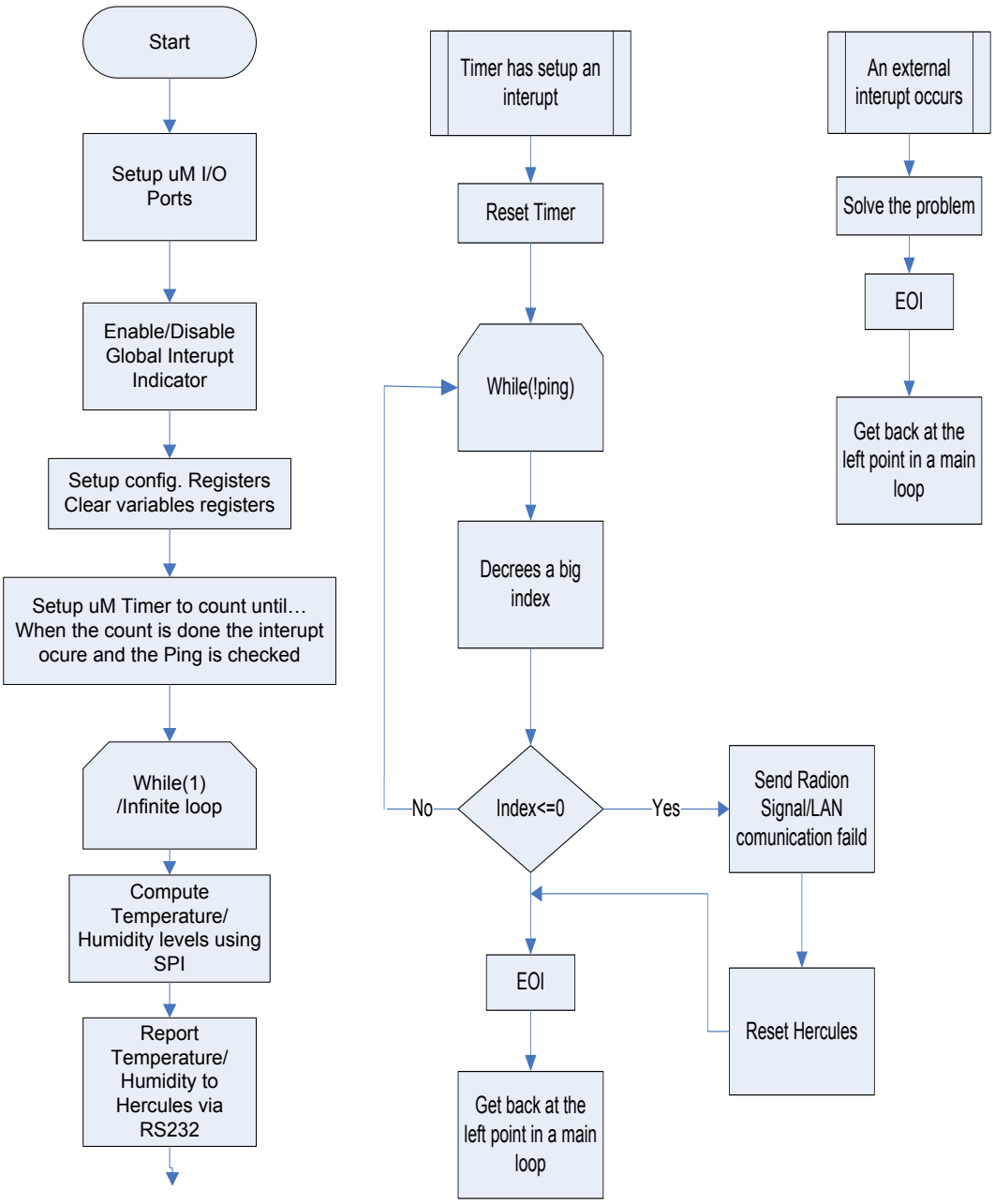


Fig. 88 Software flowchart

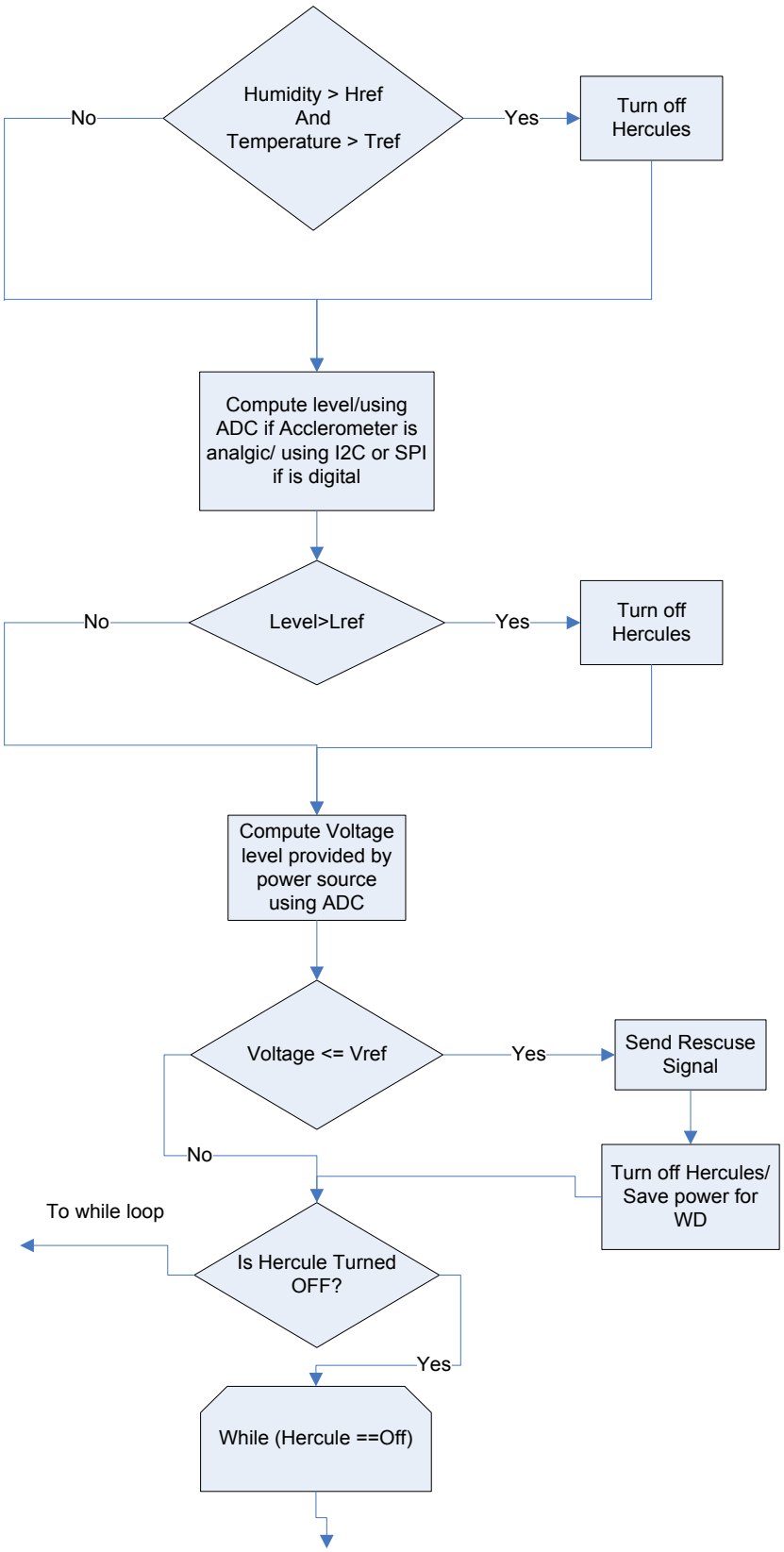


Fig. 89 Software flow chart (continuation)

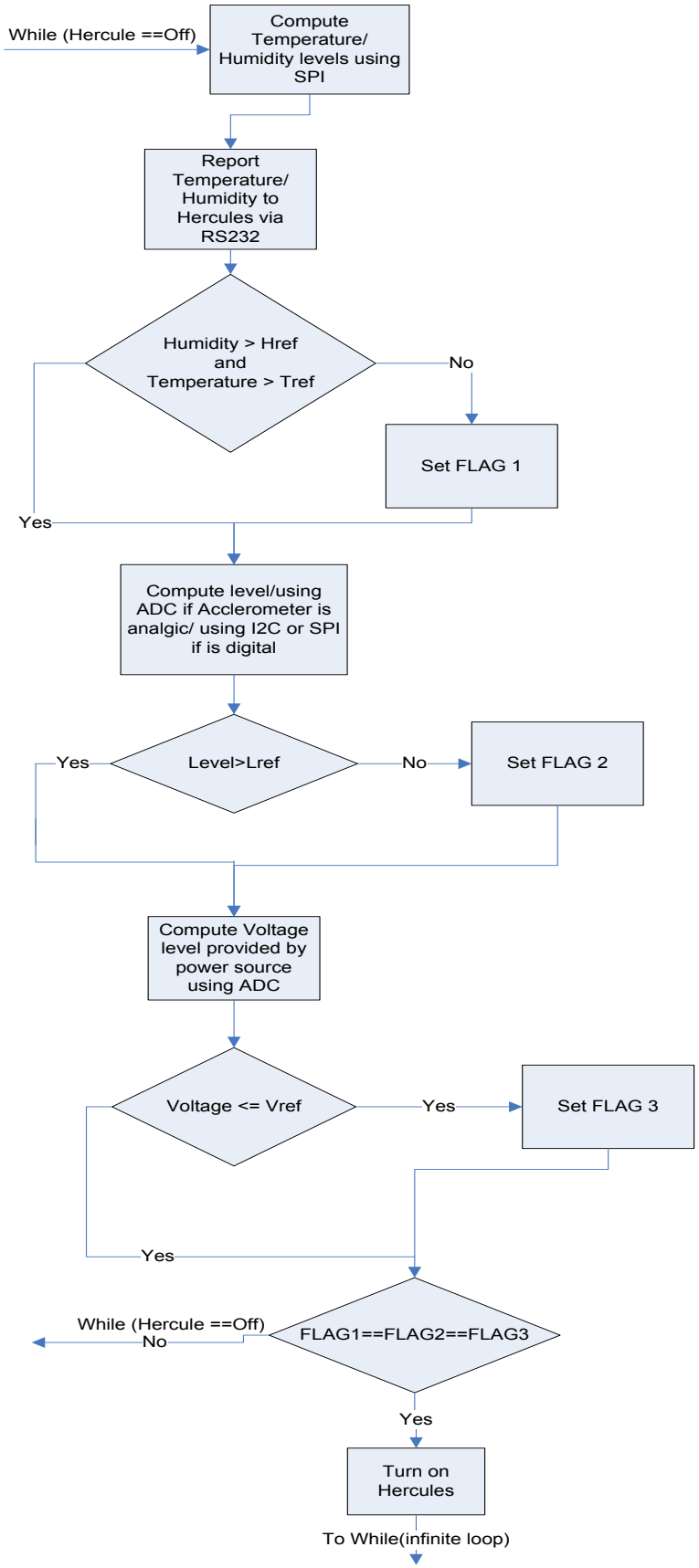


Fig. 90 Software flow chart (continuation)

Appendix 13: Detail port description of the full hardware buoy system

Wire ID	Title	Watchdog PCB connector		Description	Pin Information
		ID	Number of vias		
I.	Power supply	PA6	2	Power supply of the RF module from the watchdog due the special voltage requisites for the RF amplifier and the RF transmitter.	1. +6V for the radio amplifier. 2. +5V for the radio transmitter.
II.	Current sensing	PA8	2	Current sensing of the main battery to calculate the consumption. It should give a voltage proportional from 0 to 5V.	1. Ground. 2. Proportional voltage between +5V to 0V that represents the current consumption of the whole system.
III.	Battery control	PA7	3	Signal that is able to disconnect the main battery in case of emergency.	1. Digital control signal from PIC microcontroller. 2. +5V. 3. Ground.
IV.	Power supply	PA4	2	Power supply from the main battery to the watchdog.	1. Ground. 2. +12V, main battery supply.
V.	Enable + Signal	PA5	3	Enable and data signals needed for the RF module to execute the rescues signal.	1. Ground. 2. Digital control signal from PIC microcontroller. 3. Digital control signal from PIC microcontroller.
VII.	Power supply	-	-	Power supply of the Hercules board.	-
VIII.	Power supply	-	-	Power supply of the access point	-
IX.	Reset, on/off	PA9	2	Reset and on/off control signal to	1. Digital control signal from PIC

				control the Hercules power state.	microcontroller. 2. Ground.
X.	RS232	PA3	3	RS232 communications protocol between the Hercules and the watchdog.	1. PC-Rx. 2. PC-Tx. 3. Ground.
XI.	Live sensing	PA2	2	Periodical signal from the Hercules board to know the state of the programs running on.	1. Pc activity signal. 2. Ground.
XII.	Ethernet	-	-	Ethernet communications between the Hercules and the access point.	-
XIII.	Programming	PA1	6	PIC Kit 3 programming port.	1. !MCLR/VPP 2. Vdd Target 3. Vss Ground 4. ICSPDAT/PGD 5. ICSPCLK/PGC 6. LVP
XIV.	Amplified signal	-	-	That is the amplified signal that comes from the analogical amplifier which is between the hydrophone and the Hercules.	-
XV.	Hydrophone signal	-	-	Is the signal that we get from the hydrophone which is under the water captinwiegjweg	-

Appendix 14: Watchdog Board

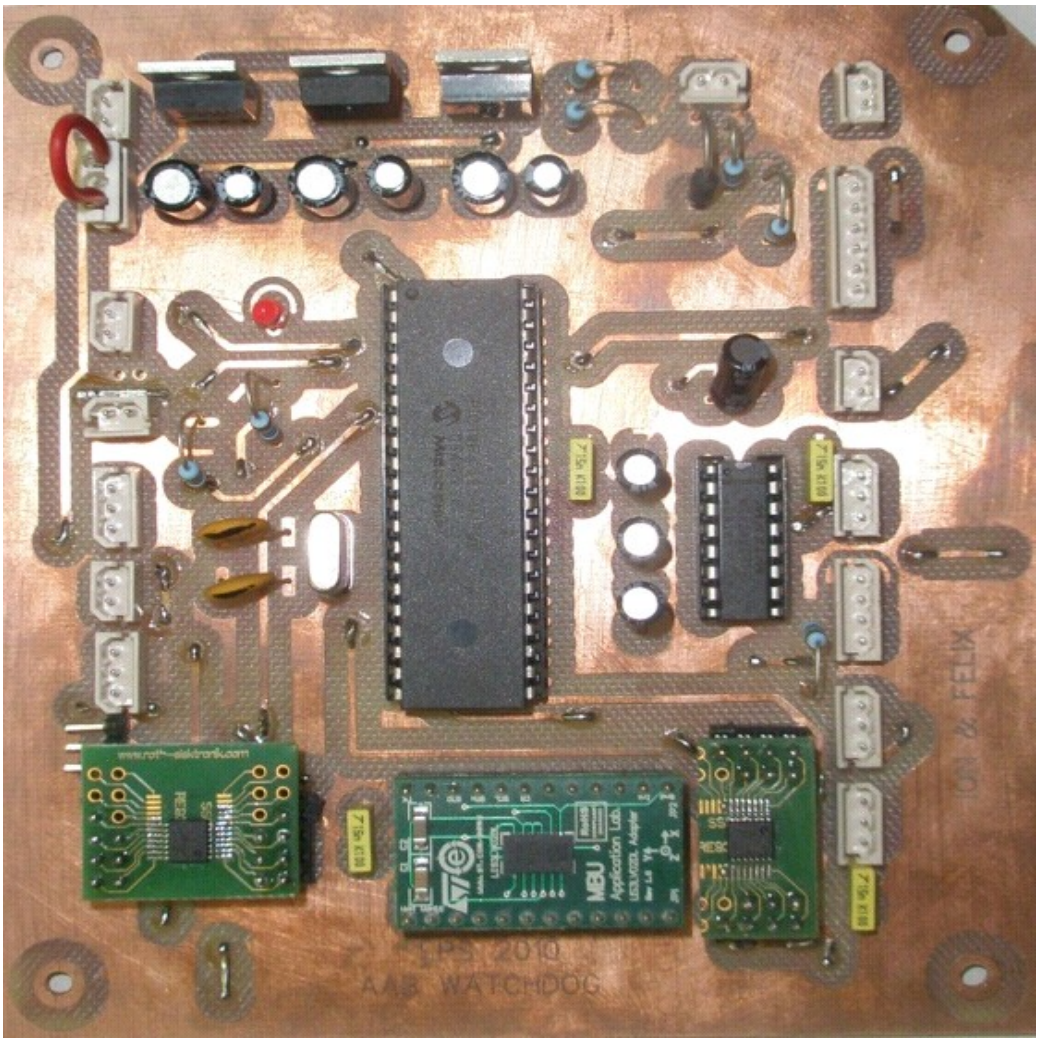


Fig. 91 Watchdog module

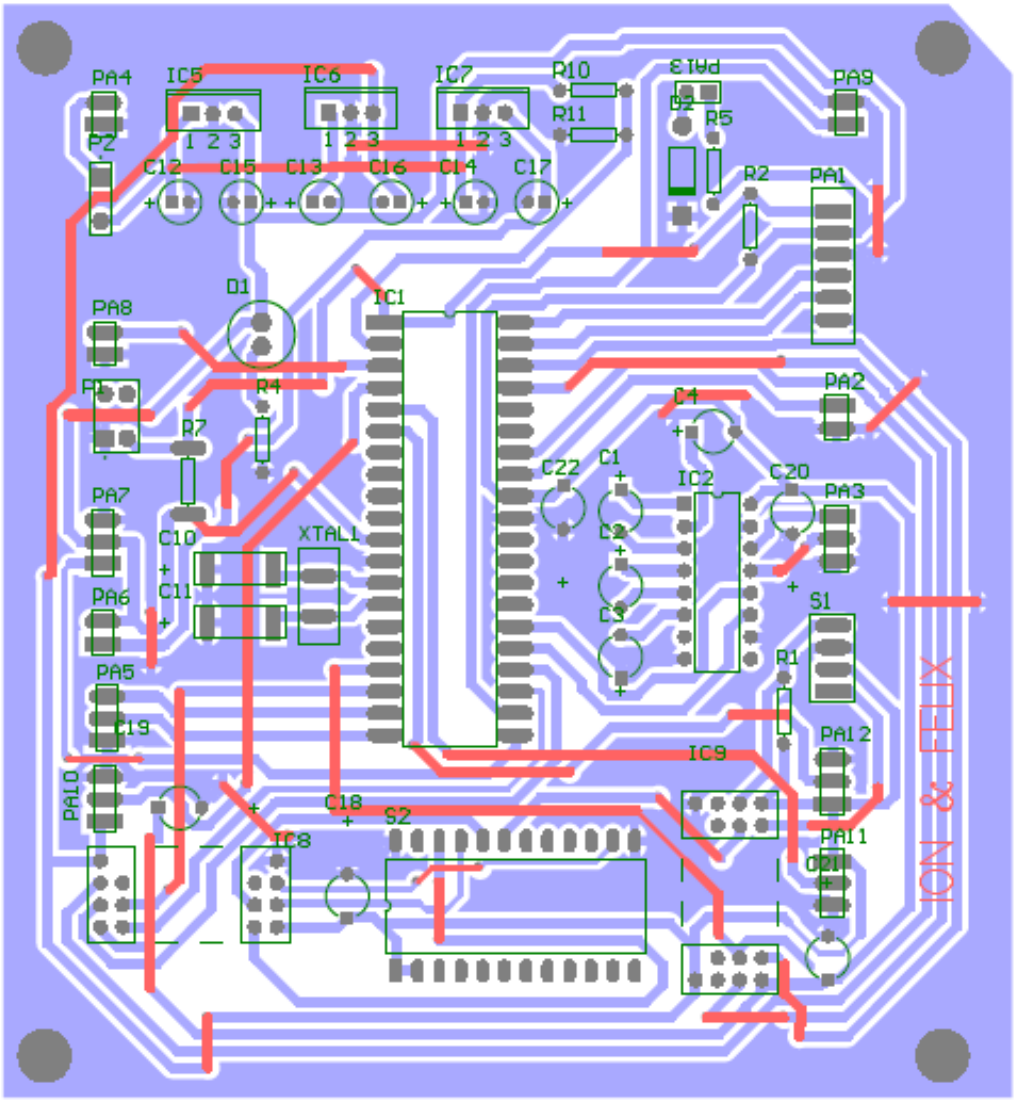


Fig. 92 Watchdog layout

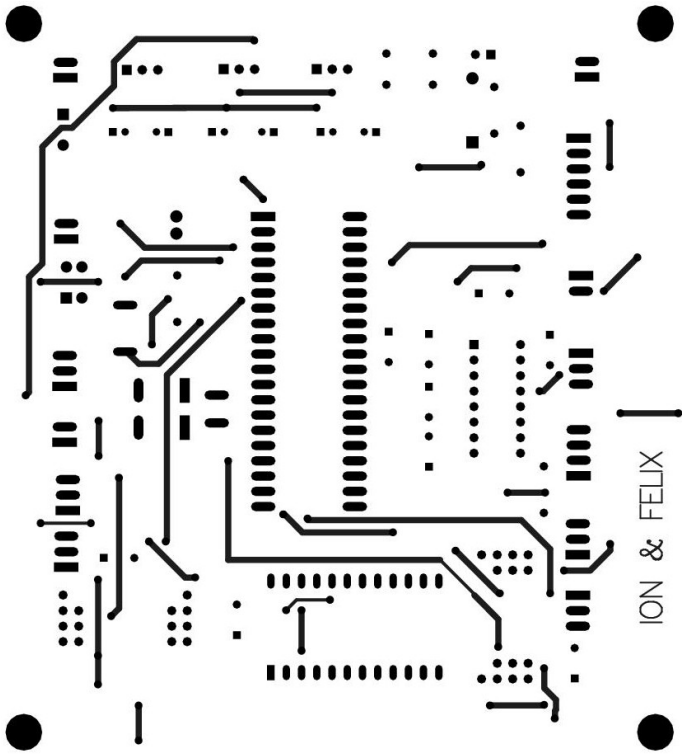


Fig. 93 Top Layout

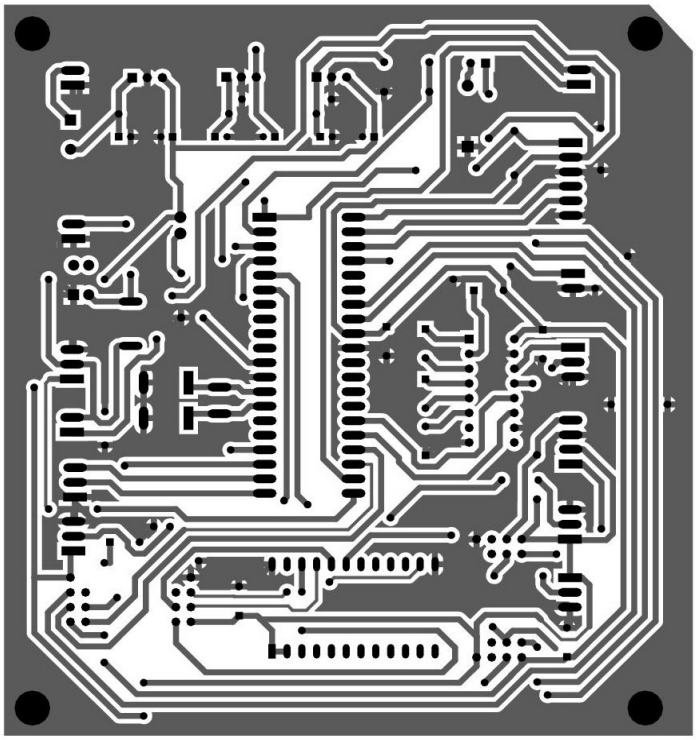


Fig. 94 Bottom Layout

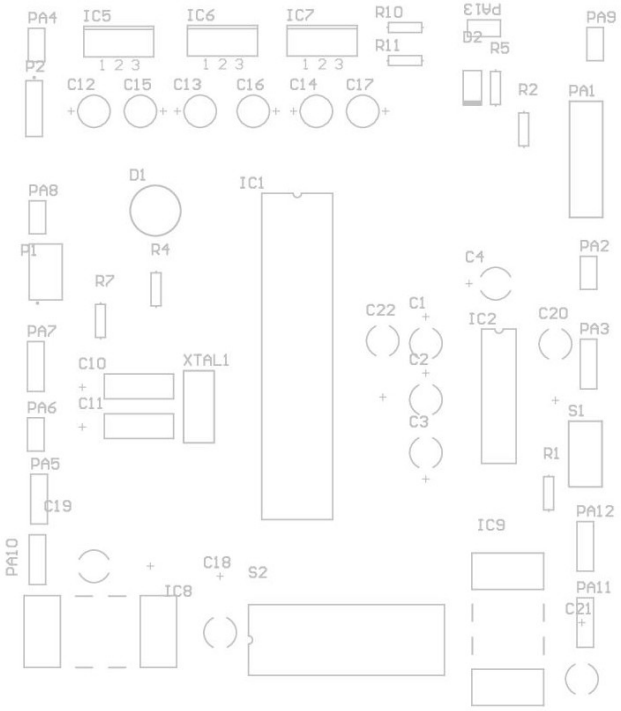


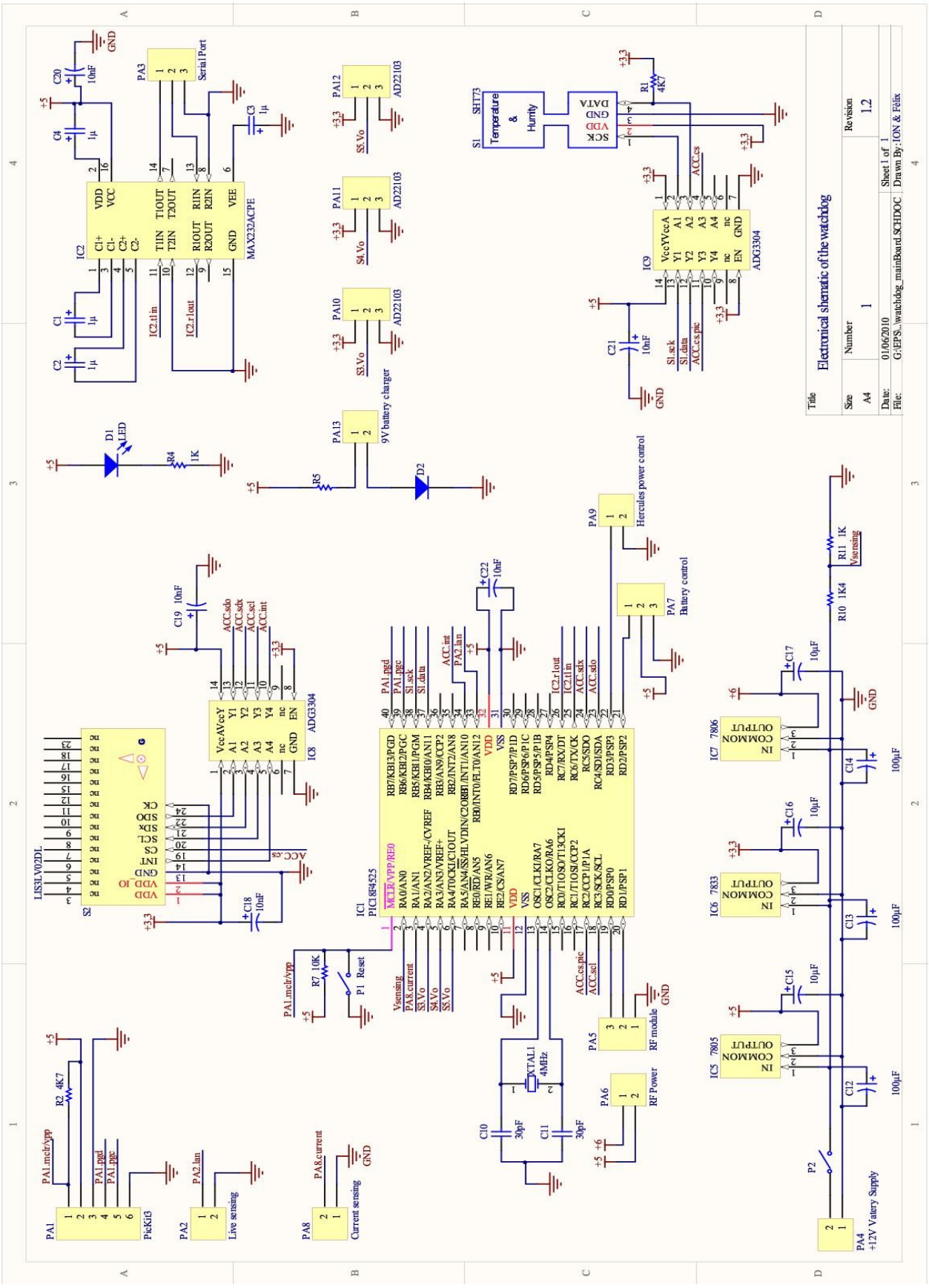
Fig. 95 Package disposition

Appendix 15: List of components

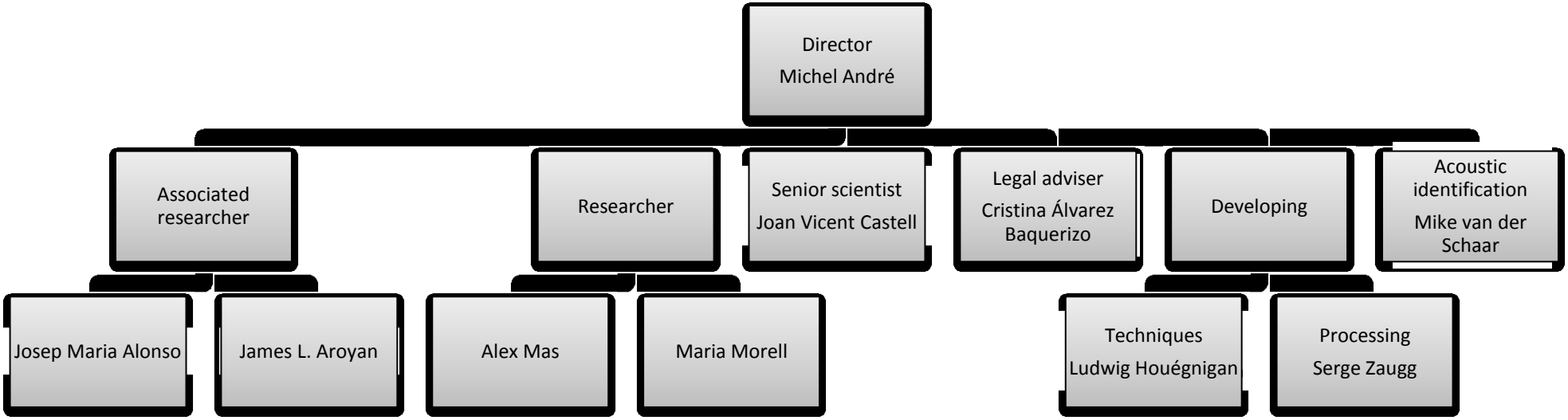
Designator	Value	Comment	Description	Quantity
C1, C2, C3, C4	1µ	MAX232 capacitor	Polarized Capacitor (Radial)	4
C10, C11	30pF	Oscillator capacitor	Capacitor	2
C12, C13, C14	100µF	78xx input voltage decoupling capacitor	Polarized Capacitor (Radial)	3
C15, C16, C17	10µF	78xx output voltage decoupling capacitor	Polarized Capacitor (Radial)	3
C18	10nF	decoupling cap of accelerometer	Polarized Capacitor (Radial)	1
C19, C20	10nF	decoupling cap of level adapter of accelerometer	Polarized Capacitor (Radial)	2
C21	10nF	decoupling cap of level adapter of sht	Polarized Capacitor (Radial)	1
C22	10nF	decoupling cap of PIC	Polarized Capacitor (Radial)	1
D1		LED	Typical INFRARED GaAs LED	1
D2		Diode for charging the 9v battery	Diode 1N4001	1
IC1		PIC18F4525	PIC microcontroller	1
IC2		MAX232ACPE	+5V Powered, Multi-Channel RS-232 Driver/Receiver	1
IC5		7805	Voltage Regulator	1
IC6		7833	Voltage Regulator	1
IC7		7806	Voltage Regulator	1
IC8, IC9		ADG3304	voltage level adapter	2
P1		Reset		1
P2		General power switch	Single-Pole, Single-Throw Switch	1
PA1		PicKit3	Header, 6-Pin	1
PA2		Live sensing		1
PA3		Serial Port	Header, 3-Pin	1
PA4		+12V Vatery Supply	Header, 2-Pin	1
PA5		RF module	Header, 3-Pin	1
PA6		RF Power	Header, 2-Pin	1
PA7		Battery control	Header, 3-Pin	1
PA8		Current sensing	Header, 2-Pin	1
PA9		Hercules power control	Header, 2-Pin	1
PA10, PA11, PA12		AD22103	Analogic temperature sensor	3
PA13		9V battery charger	Header, 2-Pin	1
R1	4K7	sht73 pull-up resistor	Resistor	1
R2, R7	4K7, 10K	reset resistor	PICkit3 pull-up resistor,	2

			Resistor	
R4	1K	LED Resistor	Resistor	1
R5	1K	resistor for charging the 9v battery	Resistor	1
R10	1K4	Res1	Resistor	1
R11	1K	voltage sensing resistor	Resistor	1
S1		SHT73		1
S2		LIS3LV02DL	Accelerometer	1
XTAL1		4MHz	Crystal Oscillator	1

Appendix 16: Schematic



Appendix 17: Organization chart



Appendix 18: Contact information companies

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